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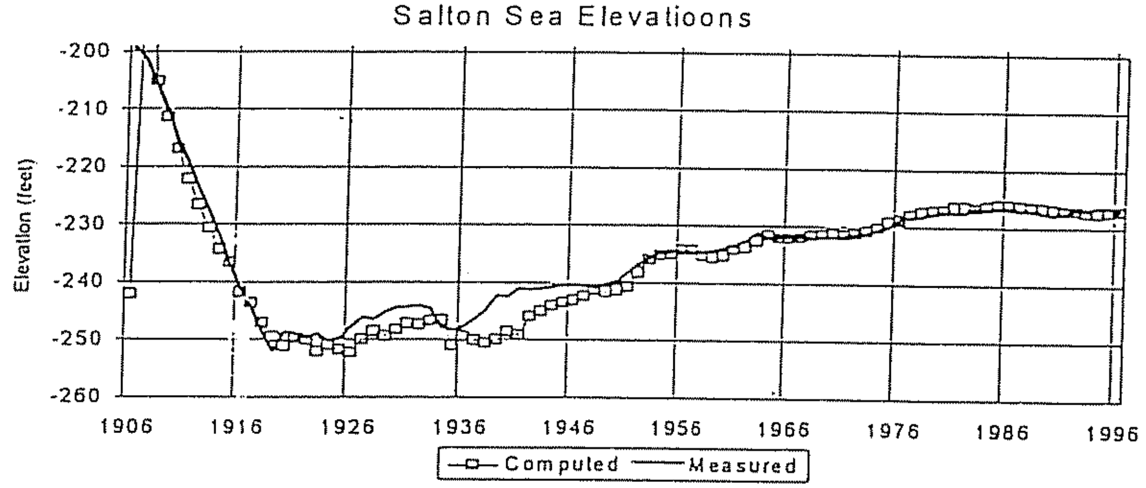
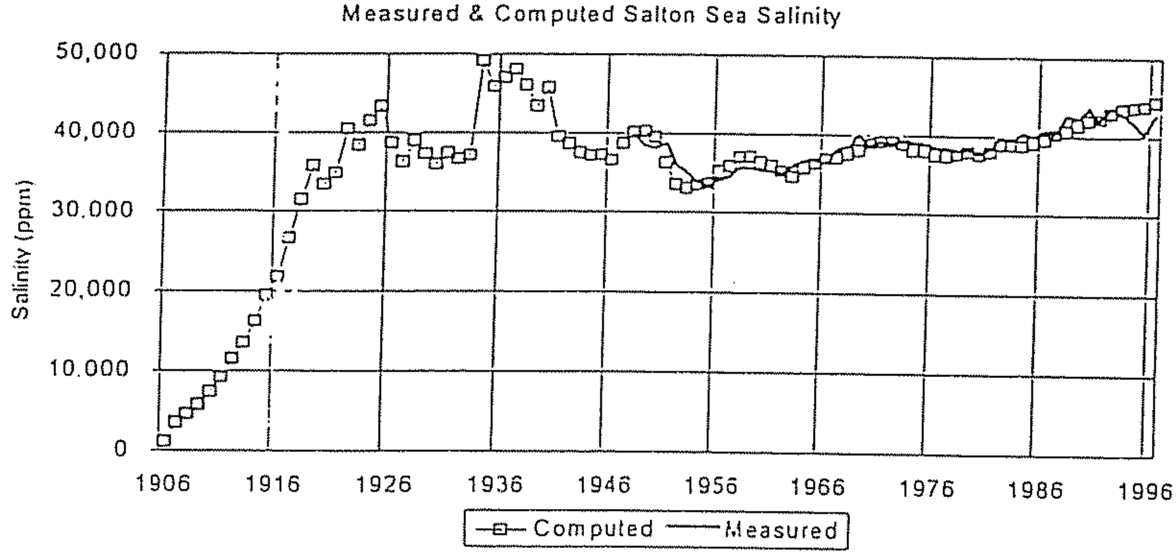
The Salton Sea 1906-1996 Computed And Measured Salinities And Water Levels





by: Merlin B. Tostrud
Colorado River Board of California

November, 1997

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Synopsis and Summary of Significant Findings

A model of the Salton Sea was developed a number of years ago by the author hereof. More knowledge has been gained of the Sea since then, hence, an examination of the current Sea's entire history was thought necessary. As much actual data as could be found for the period 1906 through 1996 was gathered. Data gaps were filled in using consideration of other information which existed during the gap period. In a few cases where no data exists, but has been investigated by others, the methodology of those previous investigations has been used to extend those findings. Measured and estimated data, along with results are tabulated in Appendix B. Dissolved solids is the only water quality parameter analyzed herein.

The major water quality finding of this study is that Salton Sea water appears to have reached its solubility limit for sulfate salts in approximately the year 1980. At that point in time, the annual salt load gain in the Sea appears to have been reduced by one-third. This resulted due to the precipitation of sulfate salts once they had entered the Sea. This is significant for a number of reasons. Depending on which annual salt gain is used, the future estimated salinity of the Sea could differ dramatically. Also, when a dike in the Salton Sea is considered as a means to create a portion of the Sea which is of lower salinity, the fresh side of the Sea would, if the findings herein are correct, not only not precipitate out sulfate salts, but, perhaps, redissolve a portion of what did precipitate following 1980. Hence, this finding, if correct, could affect expected future salinities of both sides of a diked Salton Sea. This matter requires study involving more detailed data.

Concerning water supply and consumption, three findings deserve further

attention. First, the conservation efforts which have been claimed by the Imperial Irrigation District on its own, and those in conjunction with the Metropolitan Water District of Southern California, appear to be substantiated by the study presented here. Second, it appears that when there is sustained excess water available at Imperial Dam, Imperial Irrigation District is able to significantly reduce the amount of over-order safety water because the time between water order and water delivery is reduced by a major time frame. During times of flood flows being available above Imperial Dam, Imperial Irrigation District's flow into the Salton Sea has been significantly less than when no excess water is available. Third, it appears that major overdraft of water from the Coachella Valley groundwater basin is taking place, and that there was only a short period of time, from 1950 through 1960, when the groundwater basin was not being over-drafted.

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Chapter I
Imperial Irrigation District Water Use

The California Development Company was formed in 1896 to reclaim Imperial Valley with Colorado River water. Imperial Irrigation District (IID) was organized in 1911 under the California Irrigation District Act. In 1916, IID took over the California Development Company's rights to Colorado River water. Colorado River water was first delivered to Imperial Valley on May 14, 1901 through the Alamo Canal. Until October of 1940, when deliveries through the All-American Canal began, Colorado River water was delivered solely through the Alamo Canal. From October of 1940 until February 13, 1942, IID received water from both the Alamo and All-American Canals (USGS 1954). IID currently operates and maintains a 1,675-mile canal system and a 1,457-mile drainage system.

Records were obtained from IID for both water diverted from the Colorado and for acres irrigated going back to the year 1908. Figure I-1 shows 1) deliveries to IID, 2) consumptive use of Colorado River water by crops, M&I, canal evaporation, and phreatophytes; and 3) computed

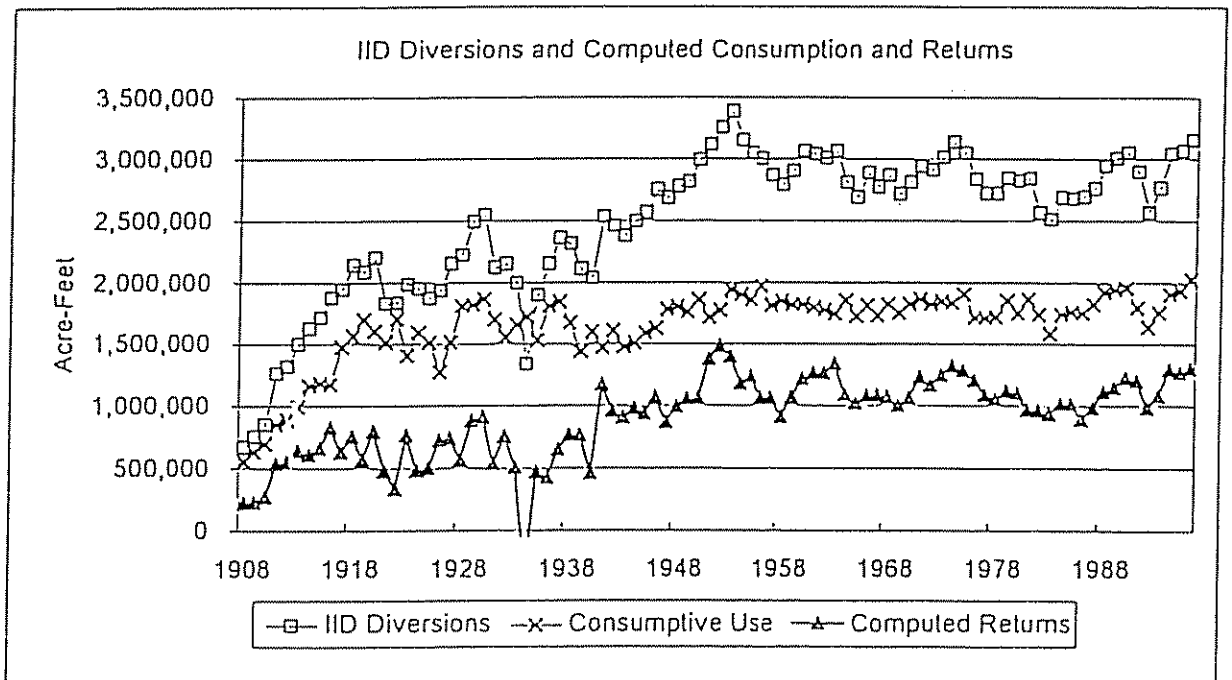


Figure I-1

return flow into the Salton Sea. Please note that consumptive use is of Colorado River water. Total consumptive use would include rainfall. It can be seen that in a number of early years, computed consumptive use is very close to equaling diversions. In fact, in 1934, computed consumptive use exceeded diversions by close to half-a-million acre-feet. It was not until Hoover Dam began storing water on February 1, 1935, that IID was assured of a year-round supply of water. Until then, high flows took place from April through July, with low flows, taking place in the remaining months, sometimes not capable of meeting IID's diversion requirements.

It is possible to make detailed studies of water use by IID because extensive long-term records are available for system inflow and outflow Also, changes in groundwater storage beneath IID irrigated soils is negligible, as described by DWR (December 1981).

IID Agricultural Unit Use Rate

A single unit use rate, 3.90 acre-feet per acre, was used throughout the study period to estimate consumptive use by IID crops, with net acreage as the crop area This value represents the total water consumed, including rainfall. This value, as with other values in the model, was derived by balancing inflow and outflow in such a manner as to optimize all constants.

Other investigators have determined unit use rates by IID. Boyle Engineering (1993, Table 6-1) computed crop consumptive use, including rainfall, for the period 1987-1992, with crop use being the residual water budget item. The average use rate was 3 908 acre-feet per acre, with a standard deviation of 0.148 acre-feet per acre IID (1996), updated the Boyle report so as to include the years 1994 and 95, with the average unit use rate dropping to 3.885 acre-feet per acre, and the standard deviation increasing to 0.152 acre-feet per acre. Jenson (1995) estimated crop consumptive use based on California Irrigation Management Information System (CIMIS) data. It is difficult to evaluate Jenson's work because the resulting unit use rates don't, perhaps, include the water rainfall supplied. Jenson's results indicate a unit use rate in the range of 3.5 acre-feet per acre, but this appears to be consumption of Colorado River water only. Also, it is interesting to note that Jenson had to multiply the unit use of alfalfa by 0 80 to make the results appear reasonable. Jenson did not present a hypothesis as to why alfalfa usage had to be reduced by twenty percent in order to create a reasonable balance. The Jensen adjustment reduced alfalfa consumptive use by approximately 280,000 acre-feet per year. The California Department of Water Resources, managers of the CIMIS stations, point out that CIMIS potential evapotranspiration data should not be used as an absolute value, but only as a reference value after a lengthy calibration has been conducted.

Parsons (1985) also derived, as a residual, crop consumptive use for IID. Table 7-1 of the Parsons report contained net acreage, but the table contained the footnote "Note: Alfalfa acreage reduced by factor of 0.793 per DWR, 1981." If the alfalfa acreage Parsons removed is added back in, the average consumptive use for the period 1975-1984 is 3.890 acre-feet per acre, with a standard deviation of 0.106 acre-feet per acre The DWR report Parsons referenced did not explain that the alfalfa acreage had been reduced, but it had been reduced by a factor of roughly 0.80. The DWR report discussed reasons for reducing the alfalfa acreage, but did not explain how the reduction factor was derived. It is quite astounding that the alfalfa acreage was reduced in the DWR report. The acreage should be left alone in such an analysis It is the potential evapotranspiration which should be reduced, and footnoted, because the acreage is a reported value, close to being actual, while the potential evapotranspiration is hypothetical. It also seems inappropriate to assign all of the reduction to alfalfa Perhaps the CIMIS station calculated potential evapotranspiration is incorrect, and the adjustment should, therefore, be allocated to all crops. Again, DWR states that CIMIS data should be used as a reference point to calibrate relative crop use, not as an absolute value. In any event, it appears, with adjustments made to the Parsons numbers, that a consumptive use rate, including rainfall consumed, of 3.9 acre-feet per acre is valid.

<u>The Use Of Net Acreage Instead Of Detailed Crop Acreage
To Compute Consumptive Use</u>

There was information in early IID records showing the acreage of four major crops, 1) cereal & seed, 2) cotton, 3) hay & forage, and 4) fruits, vegetables, & miscellaneous. Beginning in the mid-1940s, crop-by-crop acreages are available from USBR crop statistics data as reported to USBR by IID. For this study, net acreages have been used to calculate crop consumptive use rather than individual crop acreages. The use of one value per year, net acres, to compute crop consumption, is far more simple than multiplying many unit use rates times acreages of individual crops. And, from studies I've performed, the use of net acreage is just as accurate, if not more accurate, than using detailed individual crop acreages. Figure I-2 illustrates this.

The use of net acreage to compute consumptive use results (see Figure I-2) in the computed Sea elevation being, in most cases, closer to the measured elevations. Of particular note is the fairly flat elevation from 1980 on being matched closely by the use of net acreage, while the use of type of crops results in the calculated drop in elevation of four feet. I have suggested reasons why the use of net acreage is more accurate than the use of individual crops. Those include 1) in large agricultural areas, evaporating water increases humidity over the entire area. Humidity causes a reduction in evapotranspiration for all crops, but more so for crops using larger amounts of water over a longer time frame; 2) economics plays a role in the choice of crops

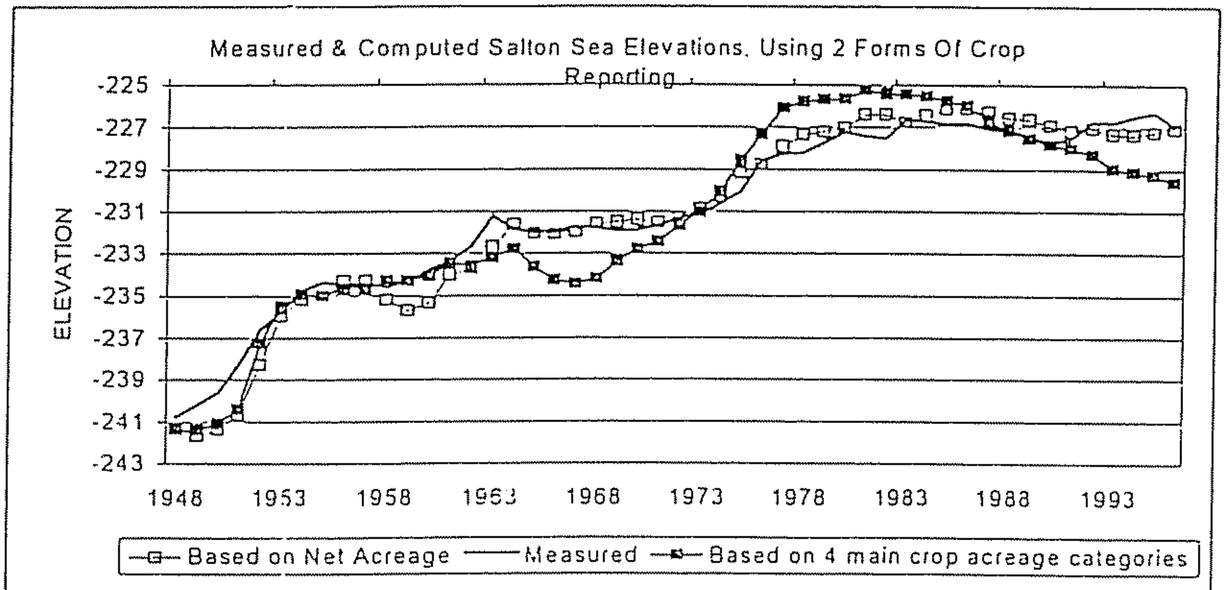


Figure I-2 illustrating that the use of net acreage gives better results than the use of type of crop planted. Figure I-3 illustrates this, showing, to a certain degree, that as IID average crop value

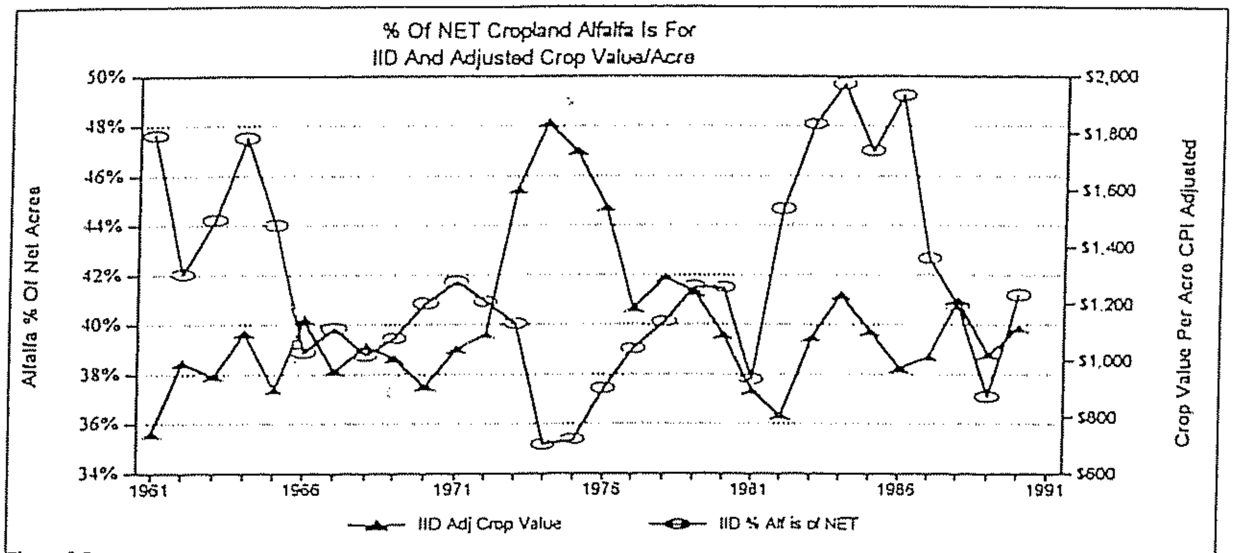


Figure I-3

per acre increases, the percentage of land which is planted with alfalfa drops. Crop value data was obtained from USBR Crop Statistics reports, and were adjusted by the consumer price index, as obtained from DWR (Vern Knoop, DWR Southern District). If high-value crops are planted because the economy will probably absorb them, the acreage of alfalfa-type crops decreases. But the demand for alfalfa is relatively constant, compared to higher-value crops, so more cuttings are made of alfalfa-type crops to keep the year's production of such crops constant. When higher-value crop acreage is reduced, there are fewer cuttings required of the increased-acreage alfalfa due to the demand being fairly constant. This reduces the amount of water used by alfalfa-type crops.

Several other reasons for using total net acreages rather than individual crop acreages include 1) not being able to specify the exact dates of pre-irrigation, planting, and harvest for each field; 2) not knowing if a rain storm destroys a field's crops or not; 3) not knowing if a crop is replanted quickly after a field's crop has been destroyed by nature; 4) not discerning that farmers may knowingly have stressed their crops, such as has been done on occasion in attempts to alleviate the effects of the whitefly pest on all crops, the boll weevil on cotton, and carnal bunt on wheat; and 5) not knowing the effects of the multitude of programs farmers have been asked to take part in to conserve water. Using individual crop acreages to compute evapotranspiration relies on some means to estimate potential evapotranspiration. It also assumes that crops use the total amount of potential evapotranspiration during their growing season. To assume that crops never run a little short on water is somewhat idealistic. And to assume devices such as CIMIS stations, the few that there are, can produce measurements, even if perfect, which, when used in hypothetical equations to compute a hypothetical amount of water evaporated ... to assume a few of these stations can accurately represent evapotranspiration over hundreds of thousands of acres

.... this also seems somewhat idealistic.

For these reasons, a single unit use rate of 3.9 acre-feet per acre, including rainfall, was applied to IID net acreage. Also, when a model is used to predict future Salton Sea environs, it would be a stretch of the imagination to predict the future's mix of crops.

Non-Agricultural Use

Table III.C.3-1 of an IID draft report (January 2, 1996) contains water delivered to non-agricultural users within IID for the years 1987 through 1994.[4] Uses included municipal, industrial, feedlots, and miscellaneous. Total water delivered went from 63,946 acre-feet in 1987 to 77,123 acre-feet in 1994. There was no estimate of water consumed, but page 69 of the report presented deliveries to and returns from the City of El Centro for calendar year 1994. From those values, it was calculated that 25% of deliveries were consumed. I assumed, however, that 33% of all non-agricultural water delivered is consumed. I obtained population statistics for Imperial County, going back to 1910, from DWR (Marla Hambright, personal communication, September 1997). The non-agricultural use for any year outside the base period of 1987-94 was derived by multiplying the average of the base period times the population in the year divided by the average population for the base period. Figure I-4 depicts model IID non-agricultural diversion and consumption.

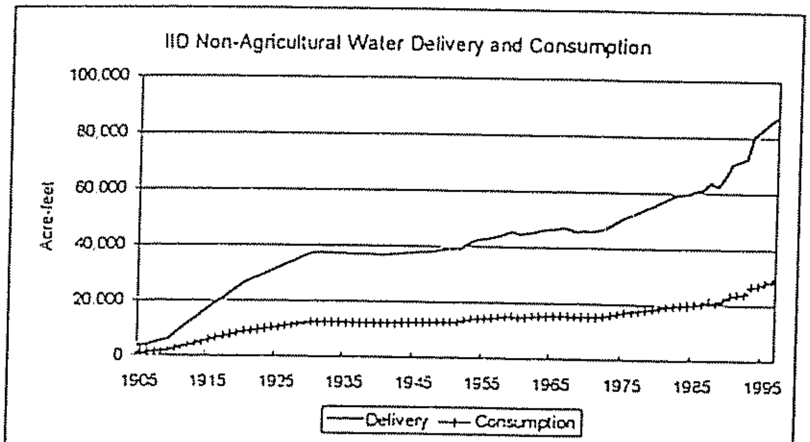


Figure I-4

The only data which could be found to check the above method for computing non-agricultural use was for the year 1983 from an IID report (January 1985). IID calculated non-agricultural delivery for the year 1983 at 56,010 acre-feet. It did not calculate consumptive use. The model, for 1983, calculated a delivery of 59,418 acre-feet. The two delivery values are reasonably close.

IID Phreatophyte Use

For the model, water consumed by phreatophytes was broken out into that by phreatophytes prior to the point of delivery to users, and after delivery to users. The model assumes that 30% of IID water lost between Drop #1 of the All-American Canal and the point of delivery to users is consumed by phtreatophytes. This is based on a report concerning lining of the Coachella Canal in which 30% of water lost from the Coachella Canal was calculated to have been consumed by phreatophytes This contradicts Boyle (August 1993 Table 6-1, page 42) which appears to return all water lost to seepage between the East Highline Canal and the point of delivery to users back into IID drains

Phreatophyte usage after delivery to users was calculated by Boyle (August 1993, page B-84) for the period 1987 through 1992, and was broken out into use along the New River, the Alamo River, and other drains Respectively, the averages were 30,012 acre-feet, 23,060 acre-

Table I-1 IID Water Usage, Part I (Acre-feet)

Period	(1) Net Acres Irrigated	(2) CRiv wat Delivered	(3) Crop CU Of CRWater	(4) Non-Irrig Con Use	(5) Phreato-phyte CU	(6) AA Canal Ground wat to Mexico
1907-16	212,584	1,232.410	759,764	3,760	140,309	0
1917-26	379,610	1,973,270	1,281,498	9,219	166,913	0
1927-36	411,675	2,103,180	1,461,817	12,125	171,578	0
1937-46	402,840	2,397,910	1,396,225	12,291	164,161	60,000
1947-56	433,809	3,021.430	1,597,190	13,347	154,396	166,322
1957-66	431,739	2.909,459	1,590,093	15,058	162,958	104,631
1967-76	437,896	2,901,841	1,596,574	15,824	162,957	97,043
1977-86	445,612	2,706.559	1,623,599	19,081	143,950	85,722
1987-96	457,362	2,924,970	1,679,424	24,447	157,395	105,413

Table I-1 (continued)

Period	(7) From Coachella Canal To EHC	(8) To IID drains	(9) IID Flow To Salton Sea Computed	(10) Measured	(11) Rainfall (In.)	(12) Temp (DF)
1907-16	0	0	414,520		3.49	71.0
1917-26	0	0	507,308		3.35	71.1
1927-36	0	0	445,326		2.78	72.1
1937-46	2,500	4.200	771,955		4.20	72.3
1947-56	21,400	21.100	1,097,397		1.40	72.4
1957-66	27,800	31,450	1.057,303	1,035,741	2.17	73.2
1967-76	27,800	47,450	1,072,879	1,057,041	2.44	72.9
1977-86	14,620	65.850	892.627	939,598	4.03	74.0
1987-96	0	51,000	974,726	975,983	2.84	73.5

feet, and 11,874 acre-feet, with the total being 64,946 acre-feet annually. The model assumes the New and Alamo River phreatophyte use to be these averages for other years. The model assumes that IID canal lining reduced phreatophyte usage by six acre-feet per mile lined, or a total reduced phreatophyte loss for the year 1990 of 21,107 acre-feet. The model therefore assumes phreatophyte use in IID's system after the point of delivery to users was 21,107 acre-feet greater in the early 1950's before canal lining began

Table I-1 summarizes, by ten-year averages, relevant IID data. Column (2) is diversion by IID at Station 1117 (below Pilot Knob) of the All-American Canal after its construction, and diverted through the Alamo Canal prior to construction of the All-American Canal. Column (1) is net acreage obtained from IID. Column (3) is computed crop consumptive use of Colorado River water. This column does not include the rainfall crops used. Column (4) is computed non-agricultural consumption, as explained above. Column (5) is computed phreatophyte usage, as explained above. Column (6) is groundwater flow to Mexico. This is all of the All-American Canal water lost between station 1117 and Drop #1, and is based on IID records. Columns (7) and (8) are computed loss from the Coachella Canal entering IID's East Highline Canal and flowing in subsurface paths to reach IID drains. Column (9) is computed IID flow to the Salton Sea, while column (10) is measured flow from IID to the Salton Sea, obtained from IID records. Columns (11) and (12) are rainfall and temperature, respectively.

Can Claimed Conservation In Imperial Valley Be Verified?

IID began conserving water in 1956 by lining delivery canals. Its ongoing conservation, along with water conserved by the MWD/IID conservation agreement, is shown in Table I-3 at the end of this chapter. Figure I-5 depicts the data. The amount conserved is difficult to quantify, and, therefore, open to interpretation.

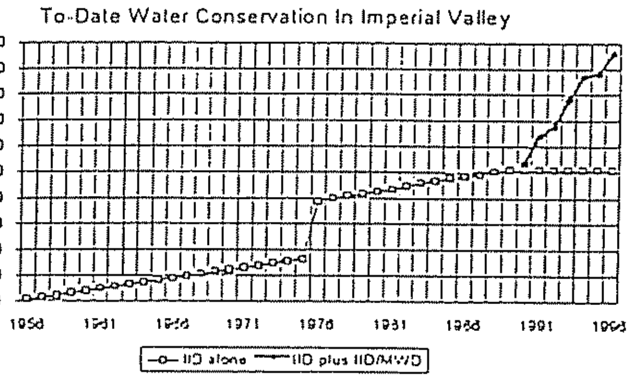


Figure I-5

Conservation was not built into the model verification except for conservation which reduced phreatophyte usage. In the verification stage of a model, actual data is used to the extent possible to judge the accuracy of model constants chosen. If the model is accurate, model flow in minus flow out should equal measured flow in minus flow out. In the case of most conservation measures, consumptive use is not altered, as the objective of most conservation measures is to reduce diversions, which should reduce return flows by a like amount. Therefore, it is not possible to include the effects of conservation in the verification stage because there is only one standard for judgement - the actual inflow minus outflow. If assumed conservation were added in, the actual results would thereby be altered, making the modification meaningless. Nonetheless, a very rough attempt at verifying conservation was made. Two ten-year periods were chosen in which rainfall was close to being equal. It is important to have rainfall in two comparative periods be equal because; 1) one inch of rain falling on today's irrigated area and on the surface of today's Sea, or a total of approximately 800,000 acres is equal to 67,000 acre-feet; and 2) the effects of rain on such matters as crop damage or crop destruction can vary greatly. It is best to have two periods as long in duration and as equal in rainfall as is possible for comparison.

The two periods chosen were 1969-78 and 1987-96. This period, fortunately, excludes most of the period of flooding on the Colorado River. Analysis of IID diversions shows a drop in drainage during the flooding years. Figure I-6 shows monthly discharge into the Salton Sea from IID, and Figure I-7 shows IID discharge to the Salton Sea and flood flows above Imperial Dam smoothed by a 60-month running average divided by 5 to represent smoothed annual data. It was hypothesized that excess water being available in the Colorado would mean IID would not have to over-order to ensure farm delivery. It takes fifty-eight hours for water, once ordered by IID, to flow from Parker Dam to Imperial Dam, two hours from Imperial Dam to Pilot Knob, and between four hours and twenty hours, depending on location, from Pilot Knob to IID farms.

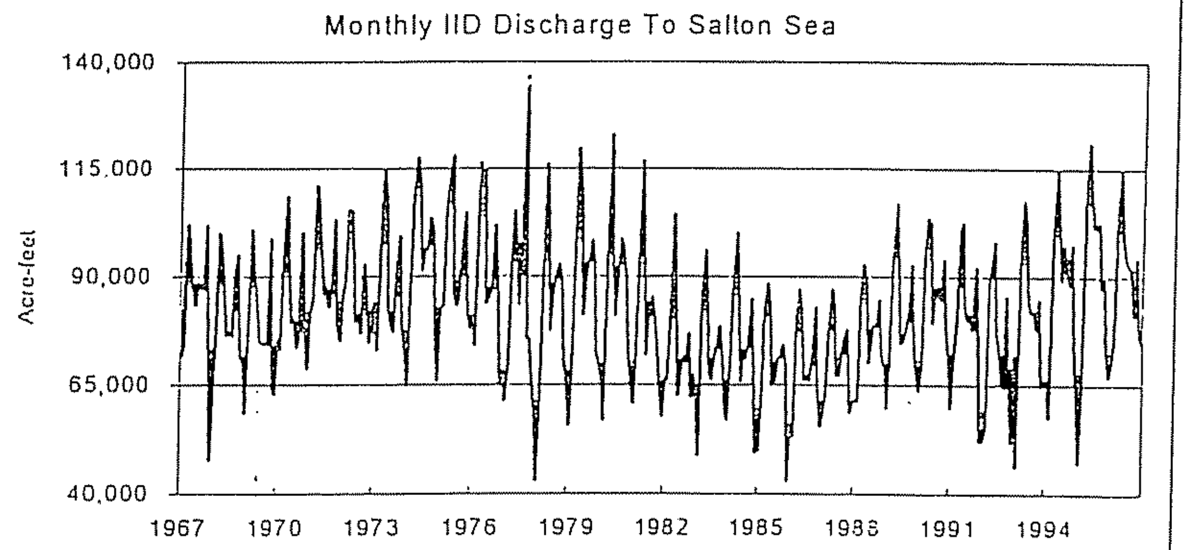


Figure I-6

Extra irrigation water must be ordered to avoid the possibility that temperatures may rise during the time it takes water to get from Parker Dam to farms, thereby stressing crops due to the unforeseen water shortage. During the high flood flow period in the 1980's, however, ordering would not need to be on the high side, as there was continuous excess flow through Pilot Knob powerplant. This, in effect, changed the point of delivery, once ordered, from Parker Dam to station 1117. There were, of course, other items which could cause the drainage to drop. Quality of water was better, meaning less might have been applied for leaching. IID was sued during this period for allegedly causing the Salton Sea to rise, so ordering may have been somewhat more cautious. And the temperature of the water was considerably lower, decreasing, by an unknown amount, water evaporation. It seems probable, however, that the opportunity to increase diversions

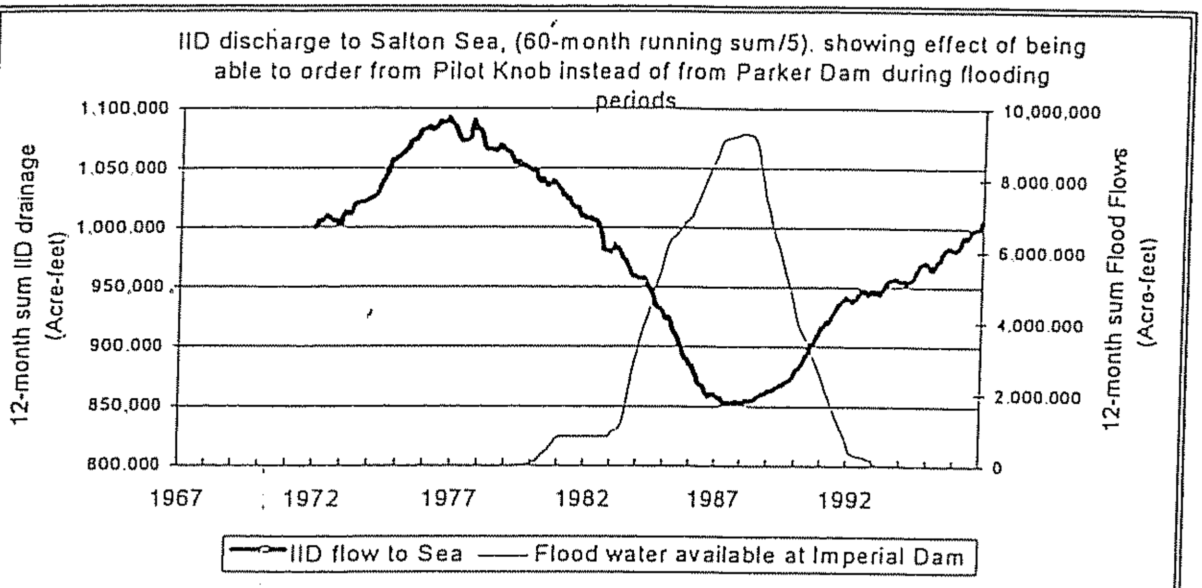


Figure I-7

almost instantaneously because excess water was available at station 1117 caused IID to order based on a far smaller margin of error. Travel time went from seventy hours to only ten hours because of the flooding.

It appears, from a cursory examination of IID drain flows shown in Figure I-7 that several hundred thousand acre-feet of water may have been involved. An IID water master confirmed that less safety water is ordered when excess water is available at Imperial Dam, but did not quantify the amount involved.

Table I-2 compares the two periods, 1969-78 and 1987-96, in order to estimate conservation. Before making adjustments, the total average annual supply was 3,076,917 acre-feet in the first period and 3,094,470 in the second. Total average annual consumption was 2,010,582 in the first period and 2,119,908 in the second. Hence, before making adjustments, consumption went up by 109,326 acre-feet, while supply went up by only 17,553 acre-feet. It could be said, prior to adjustments, that conservation had been 81,773 acre-feet per year greater in the second period. Adjustments must be made, however, for items other than rain. For adjustments other than agriculture and M&I uses, such as the flow of Coachella Canal leakage into IID's East Highline Canal, only a direct subtraction or addition was required to make the two periods equal. In the case of agriculture, the additional 16,894 acres irrigated required an estimate of increased diversion and increased return flow. To do so, the acreage was multiplied by the diversion and return flow per acre for the latter period. As stated earlier, it is assumed M&I use consumes one-third of the water diverted. The increased M&I consumption during the second period was multiplied by 3 to calculated increased diversion, and by 2 to calculate increased return flow.

After these adjustments were made, the results show that it would appear average annual conservation in the second period was approximately 152,000 acre-feet greater in the second period than in the first. An adjustment must also be made, however, because of the reduced water ordered during the flooding period, as discussed above. There were excess flows above Imperial Dam during all of 1987, and for portions of 1988. If it is assumed the total reduction in orders due to the order point being at Pilot Knob rather than at Parker Dam, then the conservation value of 152,000 acre-feet per year must be reduced by 30,000 acre-feet to 122,000 acre-feet. This is considerably larger than the 85,370 acre-feet per year average taken from Table I-3. Table I-3 lists IID/MWD conserved water available in the year shown, meaning it was partially in effect the previous year. If the ten-year period for the IID/MWD conservation agreement is advanced one year, then the total average IID and IID/MWD conservation would have been 91,161 acre-feet per year. Hence, it would appear that Table I-3 under-estimates IID historic conservation by roughly 30,000 acre-feet.

The italicized line "*Calculated return flow (check)*" in Table I-2 compares actual IID measured returns against the model's IID returns. Model return flow was 1.02% higher than measured in the first period, and 0.15% lower in the second period. Figure I-_ depicts model and measured IID returns.

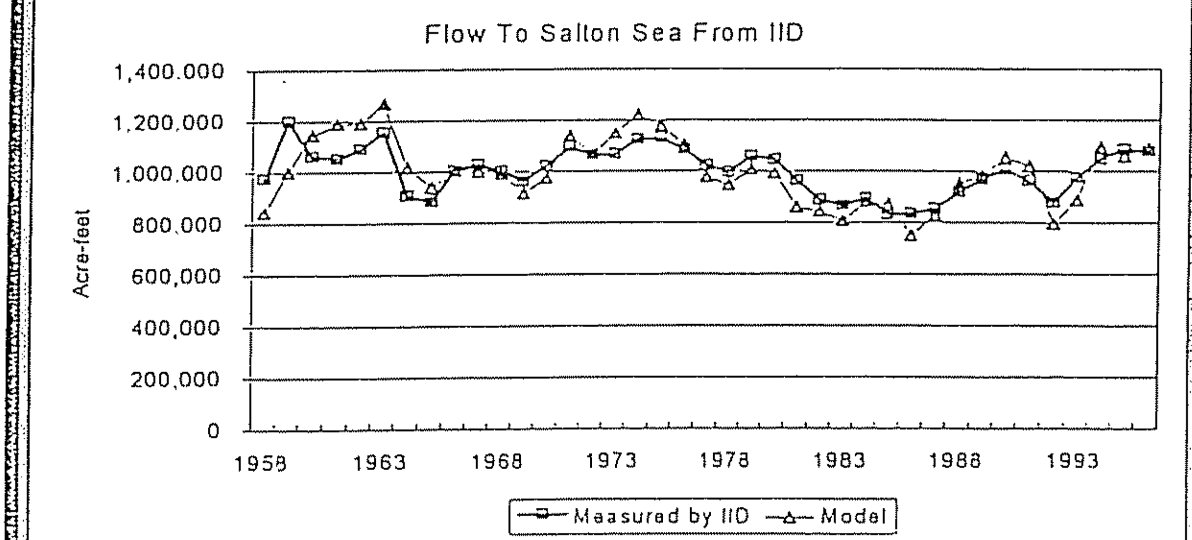


Figure I-8

The model spreadsheet included the capability to reduce or increase crop use for any year. During the 1953-96 period, crop use was increased in one year, 1963, by 5% in order to adjust for the request by USBR for a reduction in orders due to the initial filling of Lake Powell. It is assumed the reduction in orders did take place, but that the crops depleted root zone water to make up the difference. Prior to 1953, it was necessary to reduce crop usage in order to make the model replicate measured Salton Sea storage. Crop consumption was multiplied by 0.95 for the period 1906-1932, by 0.80 for the period 1933-1936, by 0.90 for the period 1937-1945, and by 0.95 for the period 1946-1952. These reductions, while necessary to make the model match reality, probably reflect history, especially during the depression years, 1933-1936 when both the great drought and the great depression reduced both the ability to grow crops and the ability to purchase food.

Table I-2 Evaluating IID conservation

Period	1969-78	1987-96	Diff.	Adjusting 69-78 to 87-96 Adjusted Diversion	Return	Con Use
Rainfall (")	2.77	2.84	0.07			
Temperature (DF)	73.09	73.46	0.37			
Net Acreage (acres)	440,468	457,362	16,894			
Supply (acre-feet)						
Diversion @1117	2,881,684	2,924,970	43,286	3,068,737	#N/A	
Coachella Canal Into EHC	27,800	0	(27,800)	27,800	#N/A	
Coachella Canal to IID drains	51,850	51,000	(850)	850	#N/A	
Total Colorado River to IID	2,961,334	2,975,970	14,636	3,097,387	#N/A	
Rainfall water supply	115,583	118,500	2,917	(2,917)	#N/A	
Total Supply	3,076,917	3,094,470	17,553	3,094,470	#N/A	
Consumption (acre-feet)						
Crop CU inc rain	1,717,825	1,783,711	65,887	100,250	34,245	66,005
Calc M&I con use	16,341	24,447	8,106	24,317	16,211	8,106
Loss 1117-EHC = Mex GW	88,749	105,413	16,664	16,664	0	16,664
Phreatophyte loss	156,512	157,395	883	883	0	883
Canal evap, etc.	44,316	44,316	0	0	0	0
Temperature adjustment	(13,362)	4,698	18,060	27,411	9,351	18,060
Total consumption	2,010,380	2,119,979	109,599	169,525	59,761	109,764
Calc. Return flow (Check)	*1,066,537*	*974,491*	*(92,047)*			
IID Measured Ret Flow	1,055,794	975,983	(79,811)			
Average conservation	98,719	184,089	85,370			
Increased conservation			85,370			
Diversion/acre for crops	6.22	5.93				
Return/acre for crops	2.32	2.03				
Con use/acre not temp adjusted	3.69	3.91				

Comparison with 1969-78 made same as 1987-96

	1969-78	1987-96	
Total supply	3,246,461	3,094,470	(151,991)
Total Con use	2,120,098	2,119,979	(165)
Returns	1,126,364	974,491	(151,807)

Table I-3 IID To Date Historic Conservation Per Colorado River Board Of California (Acre-feet)

	IID Canal Lining		Seepage	Operational	Tailwater	MWD/IID	Total	TOTAL
	Miles	Effective	Recovery	Discharge Reduction	Assessment	Agreement	IID Alone	MWD/IID
1955	0						0	
1956	27	1,620					1,620	
1957	54	3,240					3,240	
1958	81	4,860					4,860	
1959	108	6,480					6,480	
1960	135	8,100					8,100	
1961	162	9,720					9,720	
1962	189	11,340					11,340	
1963	216	12,960					12,960	
1964	243	14,580					14,580	
1965	270	16,200					16,200	
1966	297	17,820					17,820	
1967	324	19,440					19,440	
1968	351	21,060					21,060	
1969	378	22,680					22,680	
1970	405	24,300					24,300	
1971	432	25,920					25,920	
1972	459	27,540					27,540	
1973	486	29,160					29,160	
1974	513	30,780					30,780	
1975	540	32,400					32,400	
1976	567	34,020	32,291	1,000	10,000		77,311	
1977	594	35,640	32,291	2,000	10,000		79,931	
1978	621	37,260	32,291	2,000	10,000		81,551	
1979	648	38,880	32,291	2,000	10,000		83,171	
1980	675	40,500	32,291	2,000	10,000		84,791	
1981	702	42,120	32,291	2,000	10,000		86,411	
1982	729	43,740	32,291	3,000	10,000		89,031	
1983	756	45,360	32,291	4,000	10,000		91,651	
1984	783	46,980	32,291	4,000	10,000		93,271	
1985	810	48,600	32,291	4,000	10,000		94,891	
1986	837	50,220	32,291	4,000	10,000		96,511	
1987	864	51,840	32,291	4,000	10,000		98,131	
1988	891	53,460	32,291	4,500	10,000		100,251	
1989	910	54,600	32,291	4,500	10,000		101,391	
1990	910	54,600	32,291	4,500	10,000	6,110	101,391	107,501
1991	910	54,600	32,291	4,500	10,000	26,700	101,391	128,091
1992	910	54,600	32,291	4,500	10,000	33,929	101,391	135,320
1993	910	54,600	32,291	4,500	10,000	54,830	101,391	156,221
1994	910	54,600	32,291	4,500	10,000	72,870	101,391	174,261
1995	910	54,600	32,291	4,500	10,000	74,570	101,391	175,961
1996	910	54,600	32,291	4,500	10,000	90,880	101,391	192,271

Chapter II
Coachella Valley Water

This chapter will deal with historic use and supply of water in the entire Coachella Valley, changes in groundwater storage, and surface and subsurface flow of water to the Salton Sea from the Coachella Valley. Historic groundwater elevations and resulting changes in groundwater storage will be examined in an attempt to verify a water balance. Such an examination is needed for the model calibration because there is little information on how much subsurface flow has gone from the Coachella Valley to the Salton Sea, and how much water has gone into and come out of groundwater storage which, had it not done so, may have altered surface returns from the Coachella Valley.

Irrigation in the Coachella Valley began before the beginning of the twentieth century. Wells were used. In the beginning, the wells were artesian. Later on, pumps were required. Nordland (CVWD 1968), describes a study by CVWD's first field engineer, Y.P. Rowe (p 16) which concluded the lower valley could sustain only ten-thousand acres of irrigated agriculture on the valley's natural recharge. At present, CVWD irrigates roughly sixty-thousand acres. CVWD was formed in 1918. It originally included lands in the north-west area of the valley which are now in the Desert Water Agency (DWA). One of CVWD's first acts was to file for rights to water of the Whitewater River. Early on, from measurements reported annually by CVWD, it was noted that water levels were dropping. CVWD engaged in obtaining Colorado River water by an extension of the All-American Canal. The Coachella Canal, branching off of the All-American Canal, first delivered water to Coachella Valley farmers in 1949, though water was first delivered into the Coachella Canal in 1944. Groundwater levels recovered in the lower valley by the early 1960s.

Bulletin 108, prepared by the California Department of Water Resources in 1964, determined historic changes in groundwater storage for the period 1935-1957, and determined that water from the California State Water Project was needed in the upper valley to offset dropping groundwater levels. CVWD contracted for a maximum annual entitlement of 23,100 acre-feet, and DWA contracted for 38,100 acre-feet. An exchange agreement between the Metropolitan Water District of Southern California (MWD) and CVWD, and one between MWD and DWA, permits delivery of water from MWD's Colorado River Aqueduct (CRA). MWD, in return, takes DWA's and CVWD's State Project water from the California Aqueduct. A provision in both exchange agreements permits water to be delivered in advance of entitlement dates. MWD made the first exchange delivery in 1976.

Summary of Groundwater Storage Changes In Coachella Valley

Graphs herein depict this investigation's estimate of total Coachella Valley groundwater storage change. Note that this includes both DWA and CVWD areas. Figure II-1 depicts the change in groundwater storage since the year 1905. One line depicts the change in storage if there had been no MWD CRA groundwater recharge. Figure II-2 depicts annual supply, the water out, which is both consumptive use and flow to the Salton Sea, and the resulting change in groundwater storage. Figure II-3 depicts the ten-year moving average change in groundwater storage for the Coachella Valley. As can be seen from Figure II-3, during the last ten years, groundwater storage has dropped an estimated average of roughly 100,000 acre-feet per year. Without the CRA recharge, groundwater storage would have dropped close to 159,000 acre-feet per year.

Coachella Valley Water Supply

Figure II-5 depicts water supplied to the Coachella Valley. That marked as coming from the Coachella Canal is water measured at the end of the first forty-nine miles of the Coachella Canal. (The effects of leakage from the first forty-nine miles of the Coachella Canal on the Salton Sea will be discussed later in this chapter.) Supply from CRA recharge to the spreading basin near Windy Point was obtained from MWD. Natural supply was estimated using Bulletin 108. Table 13 of Bulletin 108 estimated the "Average seasonal tributary runoff in acre-feet" at 72,000. This was for the 22-year base period 1935-37, which are fiscal years. Rainfall data for the Beaumont precipitation station for the period 1907-1996 was obtained from DWR, with 1905-06 roughly estimated. The computed annual natural supply herein is simply the Bulletin 108 72,000 acre-feet per year times the rainfall for a year divided by the average Beaumont rainfall for the period 1935-1957.

Coachella Valley Water Consumption

Figure II-4 depicts water consumption in the Coachella Valley. The largest use category is that of agriculture. Crop by crop use was analyzed for 1961 through 1995 to determine CVWD crop use relative to IID's since an accurate balance for CVWD is not possible due to its groundwater basin. Unit use rates per net acre for the period were 3.90 acre-feet per acre for Imperial Irrigation District (IID), and 4.15 for CVWD. These values are for total use. Rainfall water must be removed to derive non-rainfall water consumed. As will be described elsewhere, temperature was also used in determining consumptive use, but only in a relative fashion. Acreage data for CVWD and IID for the model were, 1) 1946-1996, USBR crop reports; 2) for IID, 1908-1945, data from IID; 3) for IID pre-1908, only a rough estimate; 4) for CVWD pre-1946, benchmark acreages from Nordland. Precipitation data for both El Centro and Beaumont, California, is shown in Figure II-11. The El Centro precipitation was used to determine reduced use of non-precipitation water by crops. El Centro precipitation was compared with several short-duration precipitation records in the Coachella Valley, and found to be similar.

Golf course use is based on my July 31, 1997 memorandum and is discussed later herein. Phreatophyte water usage is the least clearly defined consumptive use item. Bechtel, in a study done for CVWD, (1967, Table 6, page 44), contains a line item "Consumptive Use By Native Vegetation In High Water-Table Areas" at 40,000 acre-feet per year. These would be the lands in Improvement District #1 supplied by Coachella Canal water underlain by a relatively impervious clay layer. Around the turn of the century, native vegetation usage was probably as high as it is today. Several historic photographs in Nordland show rather heavy native vegetation cover. The native vegetation usage was assumed to drop as time went on due to the groundwater

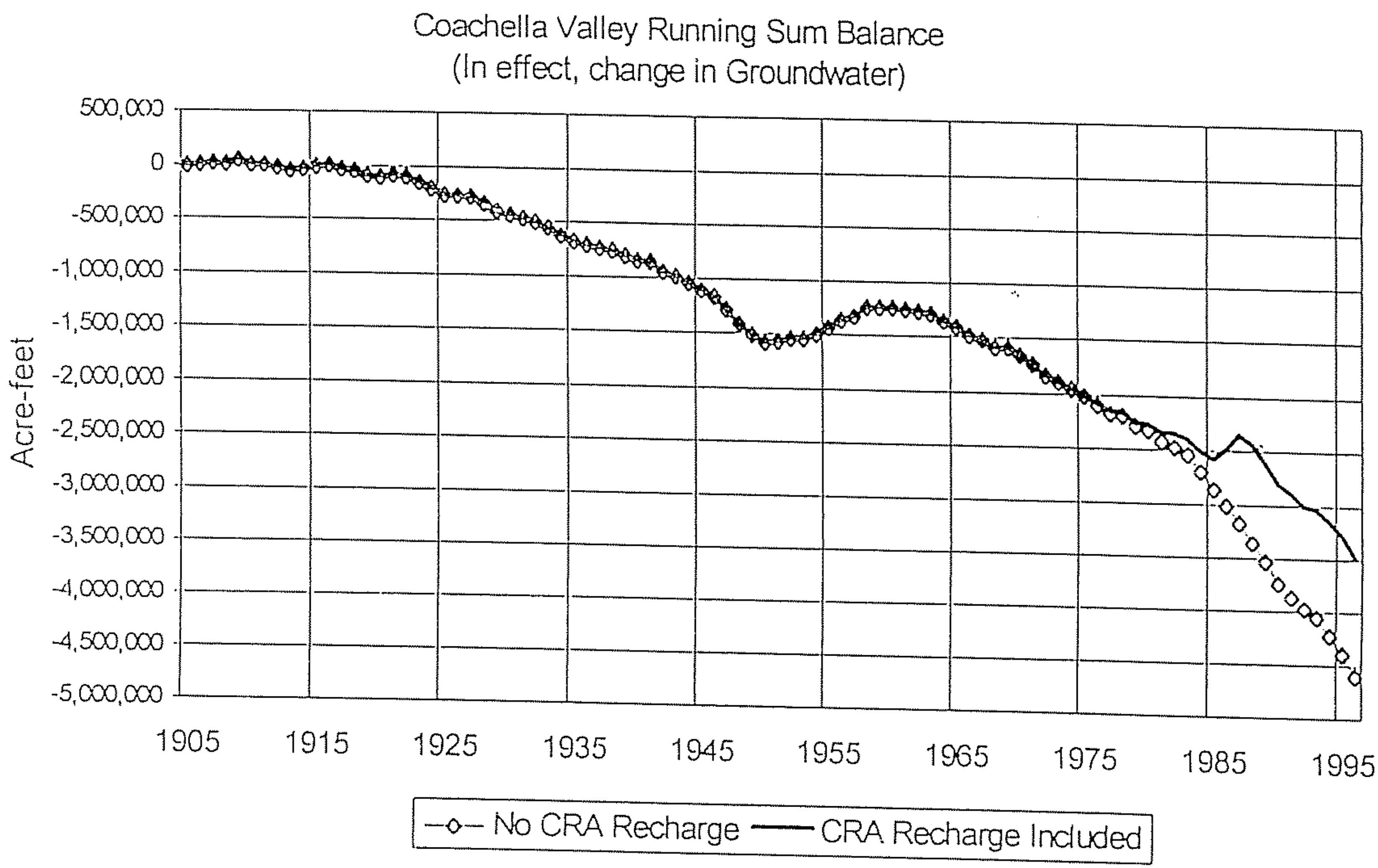

Coachella Valley Running Sum Balance
(In effect, change in Groundwater)
Acre-feet
500,000
0
-500,000
-1,000,000
-1,500,000
-2,000,000
-2,500,000
-3,000,000
-3,500,000
-4,000,000
-4,500,000
-5,000,000
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
No CRA Recharge
CRA Recharge Included

Figure II-1

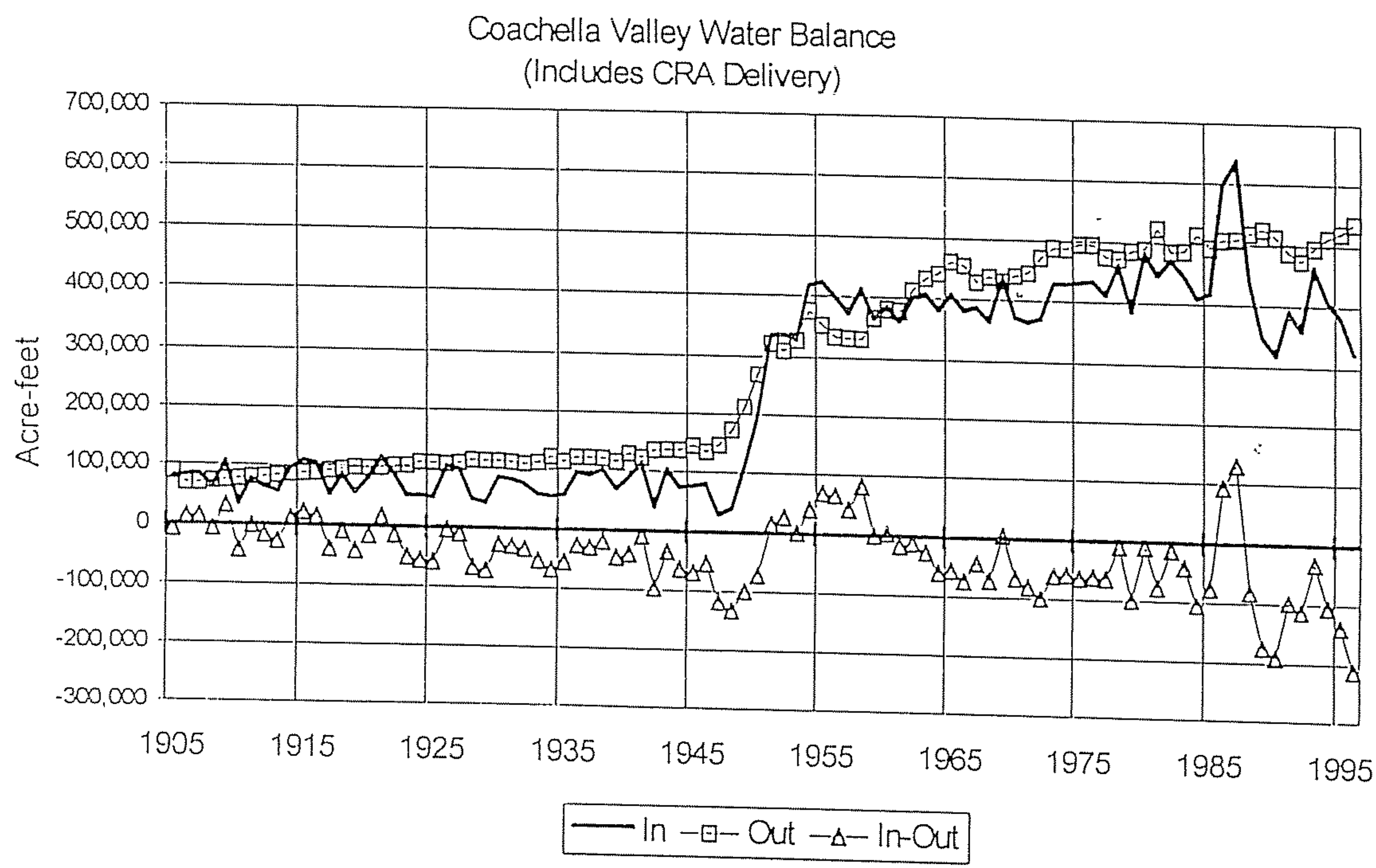

Coachella Valley Water Balance
(Includes CRA Delivery)
Acre-feet
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
-100,000
-200,000
-300,000
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
In
Out
In-Out

Figure II-2

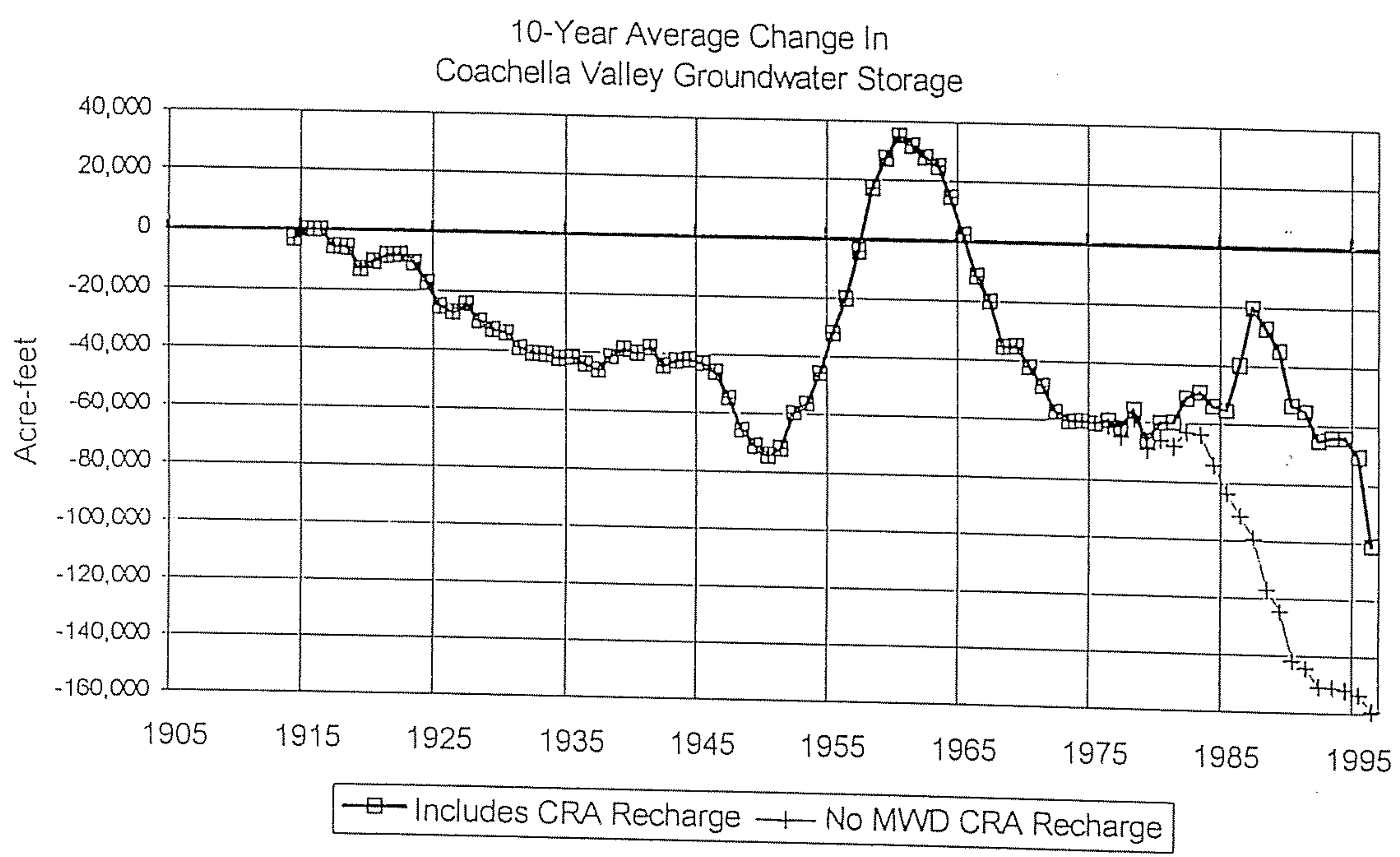

10-Year Average Change In
Coachella Valley Groundwater Storage
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
-140,000
-160,000
Acre-feet
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
Includes CRA Recharge
No MWD CRA Recharge

Figure II-3

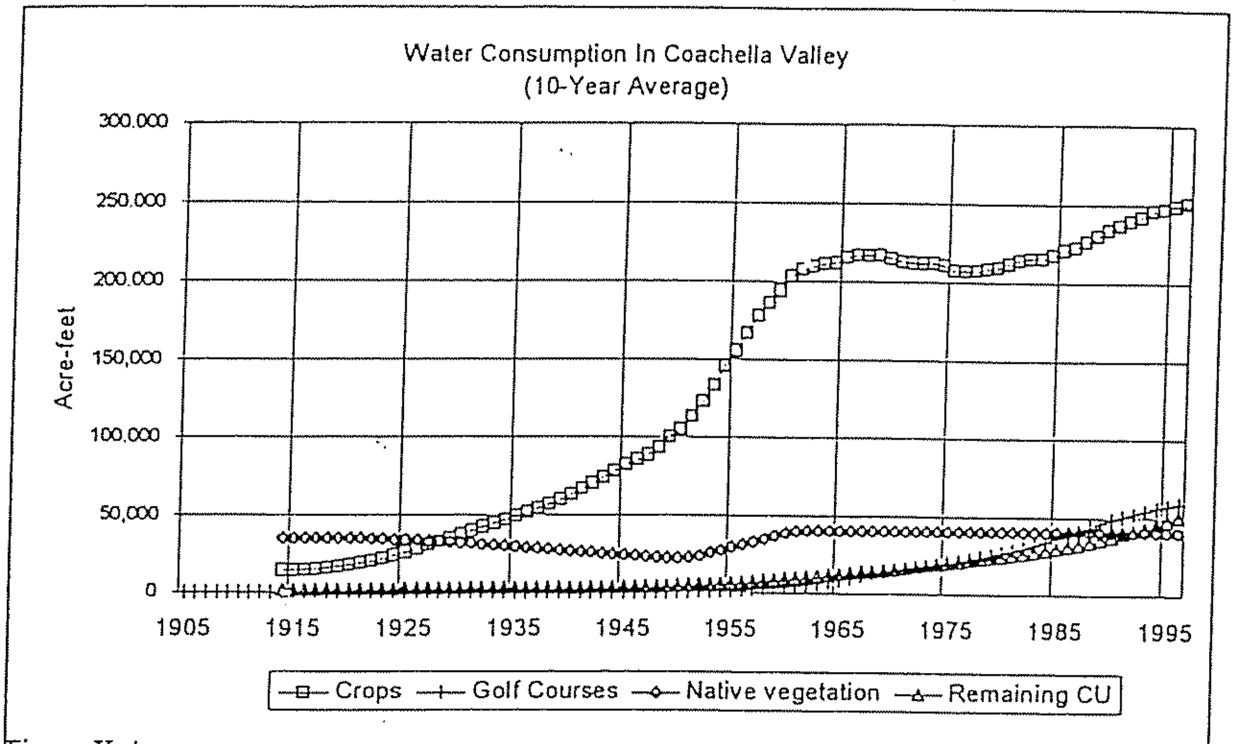


Figure II-4

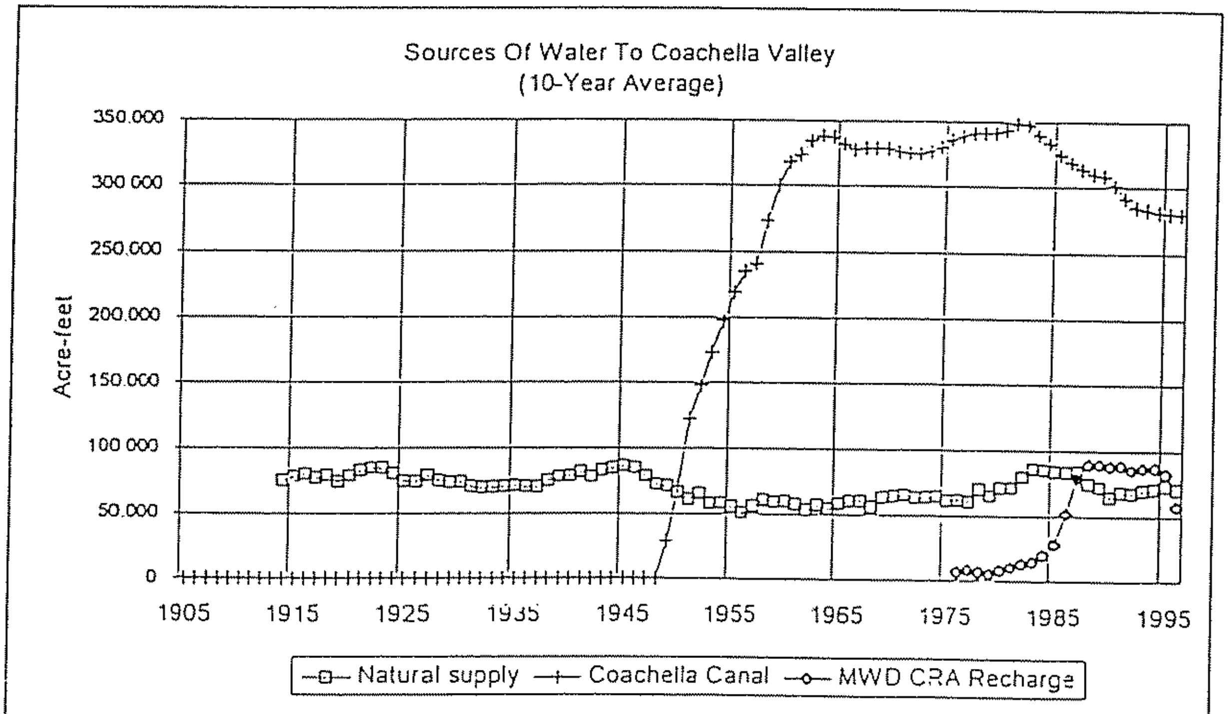


Figure II-5

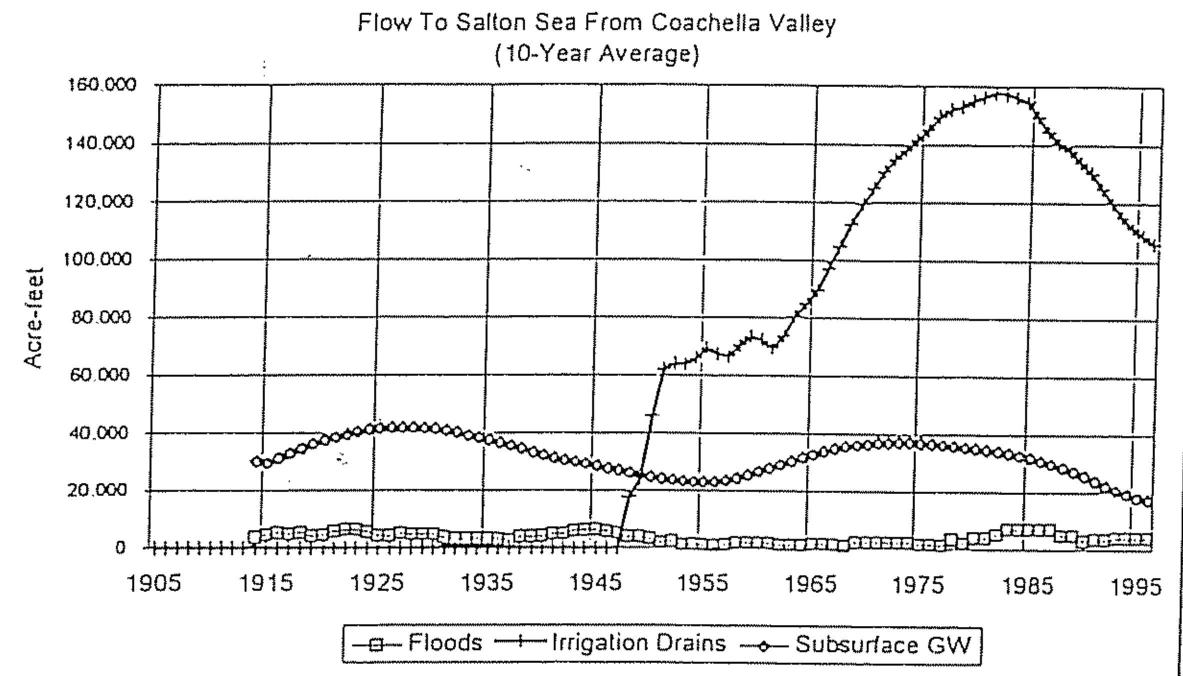


Figure II-6

level dropping, and increased back to 40,000 acre-feet per year in the early 1960s when tile drains had to be installed due to high groundwater levels on roughly two-thirds of Improvement District #1. There is no early period data on phreatophyte usage.

Remaining use in the Coachella Valley is residential, municipal and industrial, and recreational, other than golf courses. Population figures were taken from various sources, including Bulletin 108, and the DWR Bulletin 132 series. The water consumption value used was 0.210 acre-feet per person per year. This is higher than might be expected because of the large number of tourists which are not counted in population figures.

<u>Flow To The Salton Sea From The Coachella Valley</u>

The Coachella Valley contains a large groundwater basin with high storage coefficients and high transmisivity rates. This means that a mass balance of water supply and use, without considering change in storage, will not result in an accurate net flow to the Salton Sea. Either changes in groundwater storage must be factored in, or direct flow to the Sea must be estimated. After attempts using both methods were made, it was decided it would be more accurate to estimate the direct flow to the Sea and use the change in groundwater storage as a double check. Table 3 of Bulletin 108 estimated there is room for the storage of 39,200,000 acre-feet in the top thousand feet of the Coachella Valley groundwater basin.

There are three major components of flow to the Salton Sea from the Coachella Valley, surface flood flow, surface agricultural drainage flow, and subsurface flow

There is limited data on flood flow reaching the Salton Sea from the Coachella Valley. It is believed there was probably more flood flow reaching the Sea in early years due to less-stringent recharge practices Nordland contains reports on verbal accounts of floods. Most floods are a day or two in duration, and estimates of the flow were given in cfs. When floods took place prior to construction of flood-prevention dikes which served as infiltration ponds also, large areas were covered to shallow depths. In fact, from Nordland, it appears houses in the Coachella Valley were constructed on pilings to keep them out of the way of flood waters. This possibly meant that a good portion of early floods infiltrated the groundwater basin and probably provided a water supply for phreatophytes. Again, only speculation can serve to reconstruct.

Surface flood flows are minor in amount In many years, there is no surface flood flow. Most tributary water is captured for recharge Surface flow to the Salton Sea from the Coachella Valley is primarily via the Whitewater River. Annual flow past the gauging station at Indio is depicted in Figure II-7. Flow measurements at the Indio station did not begin until 1967. In

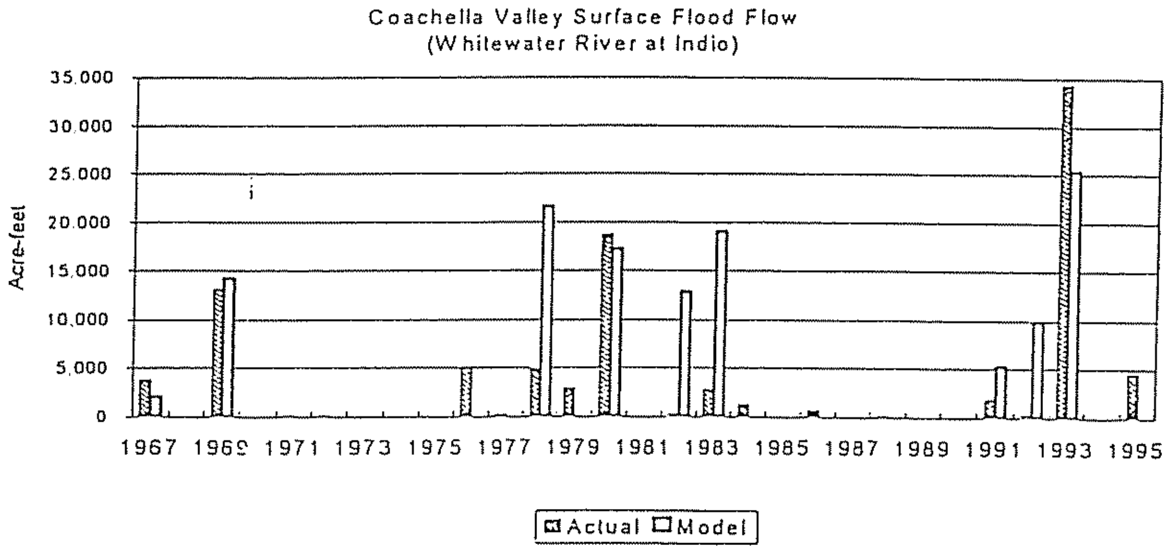


Figure II-7

many years, the flow is zero. When there is flow, it occurs for several days only. The average for the period 1967-1995 was 3,266 acre-feet per year. The Whitewater River station at Mecca measures flows at Indio plus irrigation return flows from CVWD lands irrigated with Coachella Canal water. The Mecca gage does not measure high flows accurately, so it is not possible to determine flood flow amounts from the intervening area when it takes place. An extremely rough equation was derived to estimate surface flood flows. The equation used for the model is conditional. If the virgin flow is 72,000 acre-feet or less, surface flood flow is zero. When the annual virgin flow is greater than 72,000 acre-feet, flood flow equals $(\text{virgin flow} - 72000)^{0.9}$

Figure II-7 compares actual against computed for the measured period of record at Indio. The 1967-95 measured average was 3,266 acre-feet, while the model average was 4,400 acre-feet.

Agricultural drainage flows are, presently, the major source of flow from the Coachella Valley to the Salton Sea. These flows are measured by CVWD, and records used herein are those published by CVWD, which points out that drain flows contain waters other than agricultural return flow. Since the purpose of this study was to estimate flow to the Sea, the source of the drain water is not vital. But, since CVWD drain flows averaged 113,809 acre-feet annually for the period 1948-1996, and since the natural flow supply to the valley for the same period is estimated to have been 66,110 acre-feet per year, and that most of the natural flow infiltrated into the upper valley groundwater basin, it is probable that most of the drain flow has been derived from Coachella Canal water applied to agricultural lands.

The only known published estimate of subsurface flow to the Salton Sea from the Coachella Valley is contained in Bulletin 108. Page 136 thereof says, "based on the available data, estimated seasonal subsurface outflow to the Salton Sea during the base period decreased from 33,000 acre-feet in 1935-36 to 27,800 acre-feet in 1956-57." Subsurface flow for this study was estimated using a reference groundwater surface elevation from a number of wells relatively close to the Sea, and the elevation of the Sea surface to develop a groundwater slope, with the distance between the two points being 10 miles, and the transmissivity constant set so the model closely matched Bulletin 108 subsurface flow during the base period. As can be seen in Figure II-6 showing the components of outflow to the Sea, estimated subsurface flow has averaged from roughly 40,000 to 20,000 acre-feet per year, with subsurface flow for the past ten years estimated at 17,300 acre-feet per year.

Discussion Of Coachella Valley Groundwater Data

There is a considerable amount of groundwater elevation data for the period 1957 through 1985 in California Department of Water Resources (DWR) computer files. There are also well records for the period 1985 through 1993 available in paper format. DWR has not yet entered this paper data into computer format. I entered most of those wells located in the lower valley into files in order to prepare the earlier report (June 1994), on overdraft of the lower valley groundwater basin. For this current report, it was necessary to use water level data for only a few wells prior to 1960. Pre-1960 levels were graphs in a report done for IID by Boyle Engineering (Styles, 1993). Several of the wells date back to 1926. Though these wells were in the DWR data base, they went back to only 1957. A report written by CVWD for its fiftieth anniversary (Nordland 1968) says that yearly reports were made on water levels prior to the Coachella Canal being constructed. There probably exist yearly reports on CVWD groundwater levels. However, this data is not readily available. Hence, graphs from Boyle Engineering had to be used for levels prior to 1957.

While there is a considerable amount of data on water levels, there is no direct information on amounts of water pumped from the lower valley. In the upper valley, wells are currently metered, and a pumping tax is applied. Wells in the lower valley are not metered Boyle Engineering (1993), used electrical meter readings, assumed pump efficiencies, and depth to water in order to calculate water pumped for one year only This current study could not be that rigorous. And, even if it is known how much water was pumped by wells, its ultimate disposition, be it to crop consumption, drain flow, or deep percolation, would require estimation.

Graphs are attached in Appendix A showing elevations for selected wells. The graphs begin in the upper portion of the Coachella Valley, and proceed south-west toward the Salton Sea. DWR's well numbering system is based on township, range, and section subdivisions. The figure at right depicts this numbering system. For example, well 02S04E35Q01S is located in township 2 south, range 4 east, section 35, tract Q. The 01 is a sequence number, and S indicates the San Bernardino Base and Meridian It is well known that each section is one mile square.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

California well numbering system. Top shows section numbering, bottom shows letter location in each section

Discussion of Elevations

Graphs of the northern-most wells, in Township 02 south (T2S) (page A-1) depict one of the many fault zones Bulletin 108 and Tyley (1971) describe. While wells 02S05E33E05S and 02S05E32E06S are roughly as far south as wells 02S04E35C01S and 02S04E34A01S, there is almost a 300-foot difference in groundwater level. This is due primarily to an impervious earthquake fault zone. There has been a steady decline in water levels west of the fault, but none east of the fault. Tyley (1971) contains figures showing upper valley water-level contours for the years 1936, 1951, and 1967. These can be referred to for a clear definition of the fault lines.

Township 03 south (T3S) graphs (pages A-1 through A-4) depict the effect of groundwater recharge. As stated earlier, CVWD and DWA use spreading grounds just east of Windy Point, located at the very upper north-west corner of CVWD's boundary, to spread exchange water. The spreading grounds are located at approximately section 19, T3S R4E. Table II-1 depicts historic amounts of Colorado River water spread to meet the terms of the MWD/DWA/CVWD exchange agreement Included in the table is 39,199 acre-feet of water CVWD purchased on the open market in 1996. This 39,199 acre-feet is not part of the CVWD/DWA/MWD exchange agreement At the end of 1995, MWD had delivered 383,299 acre-feet more than CVWD's and DWA's entitlement called for. This water is, in effect, banked water. MWD will, at some time in the future, withdraw this water by diverting water from the

State Water Project, but making no in-kind delivery of CRA water to the Coachella Valley.

CVWD has historically constructed works to recharge natural surface runoff water to replenish the Coachella Valley groundwater basin. CVWD filed for rights to the water early in the twentieth century. Flood-control dikes, constructed, in part, by the federal government, impound flood water along both sides of the valley and are used as recharge basins to the extent possible. Various means have been used to retard flood flows in the upper Whitewater River to enable recharge. Nordland recites valley residents' accounts of wire mesh fences placed across the stream bed of the Whitewater River near Windy Point. When the floods came, the silt would be captured by the fence and impound water which would infiltrate. There was no information to be found on the amount of water successfully replenished by infiltration of natural waters. Alterations have taken place along all reaches of the Whitewater River. The river has been confined in many areas where it once spread out thinly over the countryside when it flooded. These changes have undoubtedly reduced the amount of natural recharge, but other conservation features, such as the dike impoundments, have increased recharge, making actual recharge of natural flow water almost impossible to quantify.

Table II-1 CRA To C Valley

CYear	Acre-feet
1976	20,126
1977	13,206
1978	0
1979	0
1980	25,192
1981	26,341
1982	35,251
1983	27,020
1984	53,732
1985	83,708
1986	251,994
1987	288,201
1988	104,335
1989	1,097
1990	12,479
1991	31,722
1992	14
1993	40,870
1994	60,153
1995	36,763
1996	41,138
Total	1,153,341
/year	54,921

It can be seen that water levels in the upper 12 sections of T3S R4E have dropped continually irregardless of spreading. Water levels in T3S R6E have not changed. Levels in all other portions of T3S began increasing with spreading of CRA water. The peak occurred in 1989, and the levels have been dropping since.

Water levels in T4S (pages A-4 and A-5) dropped steadily until spreading of Colorado River water at Windy Point began, after which levels recovered somewhat.

In T5S, (pages A-5 and A-6) water levels dropped dramatically until Colorado River water spreading at Windy Point began, at which time the drop stopped, or water levels recovered slightly. T5S contains what is generally described as the dividing line between the upper Coachella Valley and the lower Coachella Valley. A map on page 3 of Swain, (1978) shows the line. It begins in approximately section 30 of T5S R7E near Point Happy and extends north-east such that it roughly intersects the most northern location of the Coachella Canal. Swain, page 2, says, "although there is no topographic divide between upper and lower Coachella Valley, the area of study corresponds with the local concept that the upper valley is separated from the lower valley by the Coachella Canal."

Swain's work was based on Tyley's Tyley (1971) modeled the same area - the west side of the upper valley. Tyley, (Figure 10, page 33), made estimates of subsurface flow from the upper valley to the lower valley. From 1936 through 1949, Tyley estimated the subsurface flow at 50,000 acre-feet annually. Then, with importation of Colorado River water into the lower valley, the gradient decreased and subsurface flow dropped to 30,000 acre-feet in 1962. Since the lower valley has never been modeled, the subsurface flow from the upper valley to the lower valley is based only on water level gradients and assumed transmissivity values. As stated earlier, a study by CVWD's first field engineer, Y.P. Rowe concluded the lower valley could sustain only ten-thousand acres of irrigated agriculture on the valley's natural recharge. Based on that study, and an assumed consumptive use rate of four acre-feet per acre, CVWD's engineer would have had to assume a subsurface flow of 40,000 acre-feet. Hence, the two estimates differ by 10,000 acre-feet, or twenty percent, which is an acceptable difference considering the limitations involved in both studies.

The amount of water flowing by subsurface paths into the Salton Sea is based on the same methodology used by Tyley to obtain subsurface flow from the upper to the lower valley. As was stated earlier herein, DWR's Bulletin 108, page 136, says, "based on the available data, estimated seasonal subsurface outflow to the Salton Sea during the base period decreased from 33,000 acre-feet in 1935-36 to 27,800 acre-feet in 1956-57."

The primary focal point of past groundwater modeling investigations has been the upper valley. There have been no models developed for the lower valley. In the upper valley, models have concentrated on the west side of the valley - the "Whitewater River Subbasin" on the west side of the Garnet Hill and Banning Faults. Neither Swain nor Tyley, in fact, modeled the east side of the upper valley.

The effect of recharge on subsurface flow of water from the upper valley to the lower valley is not well defined. It would appear that recharge using CRA water beginning in 1976 has not affected the subsurface flow into the lower valley. Some have speculated that the recharge of over 1,150,000 acre-feet of CRA water in the upper valley must have caused an increase in subsurface flow to the lower valley.

It is my opinion, however, that the recharge hasn't caused an increase in subsurface flow because increased golf course development has come close to consuming the recharge. My memo of July 31, 1997, "Historic water use by golf courses in the Coachella Valley", discusses the subject. The memo estimated there were 54 acres of golf course land in 1945, and 9,504 acres in 1997. Assuming a consumptive use of 7 acre-feet per acre, the golf courses would consume close to 66,500 acre-feet per year in 1997. Figure II-8, an estimate of Coachella Valley historic golf course use is taken from the July 31, 1997 memo. It was estimated that approximately 25% of the golf courses are located in the lower Coachella Valley. The courses in the upper Coachella Valley, during the entire period, consumed an estimated 995,000 acre-feet. During the period of CRA recharge, 1976-97, the upper valley golf courses consumed an estimated 808,500 acre-feet. 1,150,000 acre-feet of CRA water was recharged during the 22-year-long period.

Water levels had been dropping in the upper valley prior to importation of CRA water Hence, it is more than likely that the increased non-golf-course use, along with the increasing golf course use, more than consumed the CRA importations. This is why it is probable none of the imported CRA recharge water reached the lower valley.

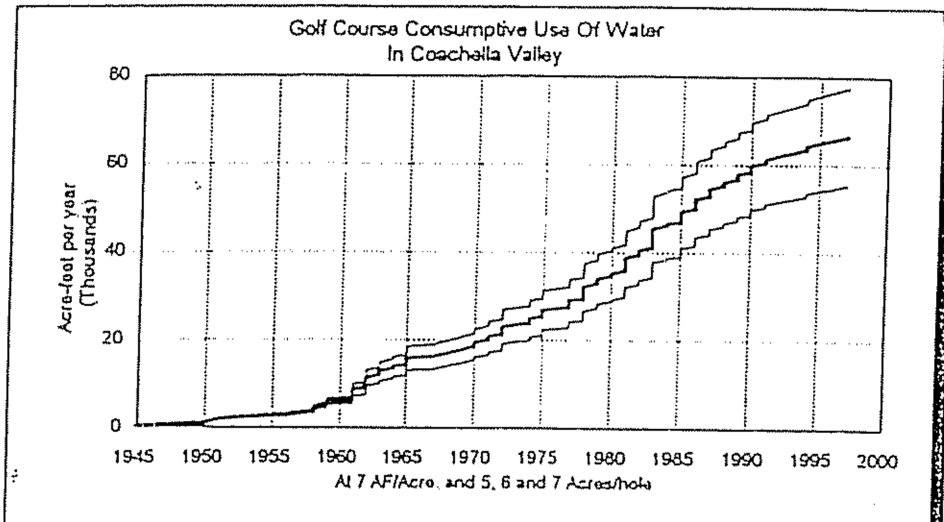


Figure II-8

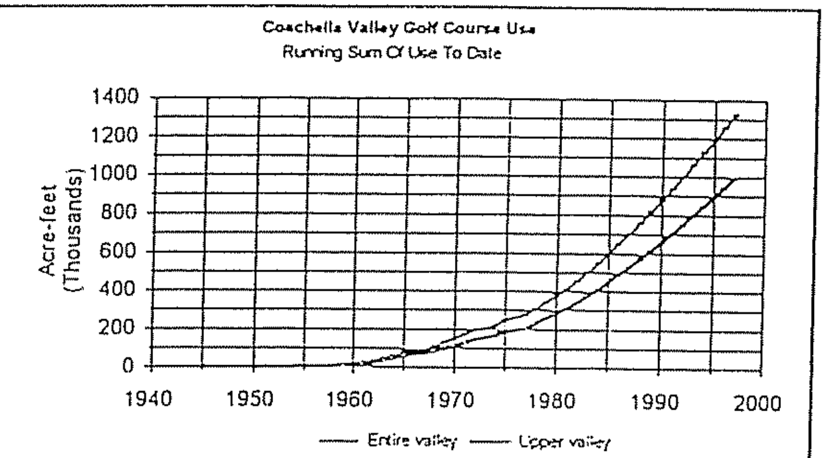


Figure II-9

DWR's data for Bulletin 108 showed groundwater levels were dropping in the upper valley, and that State Water Project water was required if the trend was to be thwarted. In 1957, the last data Bulletin 108 was based on, golf courses were using only 2,900 acre-feet per year. Both DWA and CVWD contracted for SPW, CVWD for 23,100 acre-feet, and DWA for 38,100 acre-feet, or a total of 61,200 acre-feet annually. This water is less than the estimated current needs of golf courses in the Coachella Valley.

Water level graphs (pages A-6 and A-7) show that water levels have stayed quite constant in T6S.

T7S graphs (page A-8) show the steady decline in water levels until 1949 when Colorado River water was first imported through the Coachella Canal Then the levels rose until about 1965. Following that, levels dropped slowly until about 1980 After 1980, levels began to drop rapidly

Graphs of T8S (page A-8) show the same thing as in T7S In T8S, however, water levels have, in recent years, dropped to or below the elevation of the water surface of the Salton Sea

The drop in some wells has been sixty feet during the period 1982-1993 Pumping from several of these wells ceased when the water level dropped below the elevation of the Salton Sea. It is assumed water quality deterioration was the cause. Salton Sea salinity, even then, exceeded that of ocean water.

A graph of T9S (page A-9) shows a gradual, continual drop in water levels.

Page A-9 contains a graph of the average of 103 wells in the lower Coachella Valley for the period 1983 through 1993. This data was available for so many wells because of the work done on the June 1994 report on CVWD overdraft. Page A-10 contains a very rough estimate of the groundwater slope from point to point in the lower Coachella Valley during this period. The legends on the graph mean, as follows; 1) SS to #1 = slope of water table from the Salton Sea to wells in T8S south of section 23; 2) SS to #2 = slope of water table from the Salton Sea to T8S north of and including section 23; 3) #2 to #3 = slope from T8S to T7S; 4) #3 to #4 = slope from T7S to T6S; and, 5) #4 to #5 = slope of water table from T6S to T5S.

Figure II-10 represents the groundwater elevations used in the Salton Sea model to

Table II-2

Difference Between Groundwater And Salton Sea Surface (feet)

Year	Elev. Wells	Elev. Sea	Diff	Year	Elev. Wells	Elev. Sea	Diff	Year	Elev. Wells	Elev. Sea	Diff
1926	-141.7	-248.7	-107.0	1949	-183.8	-239.8	-56.0	1972	-135.2	-230.7	-95.5
1927	-139.2	-246.8	-107.6	1950	-184.8	-239.4	-54.6	1973	-135.9	-230.4	-94.5
1928	-139.2	-245.7	-106.5	1951	-184.3	-238.3	-54.0	1974	-138.8	-230.1	-91.3
1929	-140.2	-245.7	-105.5	1952	-177.0	-237.0	-59.3	1975	-137.6	-229.5	-91.9
1930	-142.7	-244.3	-101.6	1953	-175.1	-236.0	-60.9	1976	-138.2	-228.7	-90.5
1931	-147.2	-243.0	-95.8	1954	-172.3	-234.8	-62.5	1977	-139.8	-228.1	-88.4
1932	-154.7	-243.6	-88.9	1955	-168.9	-234.2	-65.3	1978	-140.9	-227.5	-86.5
1933	-159.7	-243.5	-83.8	1956	-164.7	-233.8	-69.1	1979	-141.5	-227.3	-85.7
1934	-160.7	-244.8	-84.1	1957	-162.4	-234.0	-71.3	1980	-144.3	-226.5	-81.8
1935	-161.7	-247.8	-96.1	1958	-155.2	-233.8	-78.6	1981	-141.5	-226.4	-85.0
1936	-162.7	-247.6	-84.9	1959	-151.4	-233.9	-82.5	1982	-144.4	-226.8	-82.4
1937	-164.7	-246.5	-81.8	1960	-147.0	-233.4	-86.5	1983	-147.9	-226.4	-78.5
1938	-166.7	-245.2	-78.5	1961	-144.0	-233.1	-89.1	1984	-152.2	-226.0	-73.8
1939	-166.7	-243.7	-77.0	1962	-141.4	-232.7	-91.2	1985	-157.0	-226.1	-69.1
1940	-167.2	-242.1	-74.9	1963	-140.0	-231.7	-91.7	1986	-163.6	-225.1	-62.5
1941	-170.3	-241.3	-71.0	1964	-137.9	-233.7	-92.7	1987	-165.9	-226.4	-60.5
1942	-170.5	-240.6	-70.1	1965	-135.9	-231.5	-95.5	1988	-171.6	-226.3	-54.6
1943	-170.8	-240.7	-69.9	1966	-134.6	-231.4	-96.8	1989	-174.7	-226.6	-51.9
1944	-171.8	-240.3	-68.5	1967	-134.2	-231.5	-97.2	1990	-182.9	-226.9	-44.0
1945	-173.9	-240.6	-66.7	1968	-134.2	-231.1	-96.9	1991	-193.6	-226.9	-33.3
1946	-174.5	-239.8	-65.2	1969	-134.5	-231.1	-96.6	1992	-187.9	-225.4	-37.5
1947	-177.9	-239.8	-61.9	1970	-136.2	-231.1	-94.9	1993	-187.0	-225.0	-37.9
1948	-180.9	-240.1	-59.2	1971	-134.1	-231.2	-97.1				

determine subsurface flow to the Sea It is the average groundwater elevation of four wells. The wells are 08S08E24L01S, 08S09E33N01S, 07S08E34G01S, and 07S07E03A01S The first two

Table 3 of DWR's Bulletin 108

ESTIMATED GROUND WATER STORAGE CAPACITY AND AMOUNT OF GROUNDWATER IN STORAGE
COACHELLA VALLEY GROUND WATER BASIN
(In acre-feet)

Area	Total storage capacity /a		Storage capacity available in first 20 feet above spring 1961 water levels/b		Ground water in storage, spring 1961: Amount stored in first 20 feet below water table		Amount stored in first 60 feet below water table	
San Gorgonio Pass Subbasin		2,700,000		81,000		31,000		245,000
Mission Creek Subbasin		2,400,000		32,000		30,000		254,000
Desert Hot Springs Subbasin								
Miracle Hill subarea	400,000		0 c		13,000		40,000	
Sky Valley subarea	1,400,000		0 c		47,000		141,000	
Fargo Canyon subarea	2,300,000				112,000		336,000	
		4,100,000		c				
						172,000		517,000
Indio Subbasin								
Garnet subarea	1,000,000		33,000		34,000		100,000	
Palm Springs subarea	4,600,000		225,000		220,000		670,000	
Thousand Palms subarea	1,800,000		33,000		25,000		50,000	
Oasis subarea	3,000,000		0 c		82,000		247,000	
Thermal subarea	19,400,000							
Semiperched ground water			0 c		339,000		371,000	<-orig374,000
Aquifers (unconfined)			160,000		211,000		603,000	
		29,800,000		451,000		335,000		2,531,000
		------------		---------				
COACHELLA VALLEY GROUND WATER BASIN		33,200,000		564,000				3,597,000

a. Capacity to store groundwater between 1935-36 high ground water elevations and 1,000 feet below the ground surface.
b. Limited by 1935-36 high ground water levels.
c. Storage capacity between 1935-36 high ground water levels and spring 1961 ground water levels negligible or undetermined.

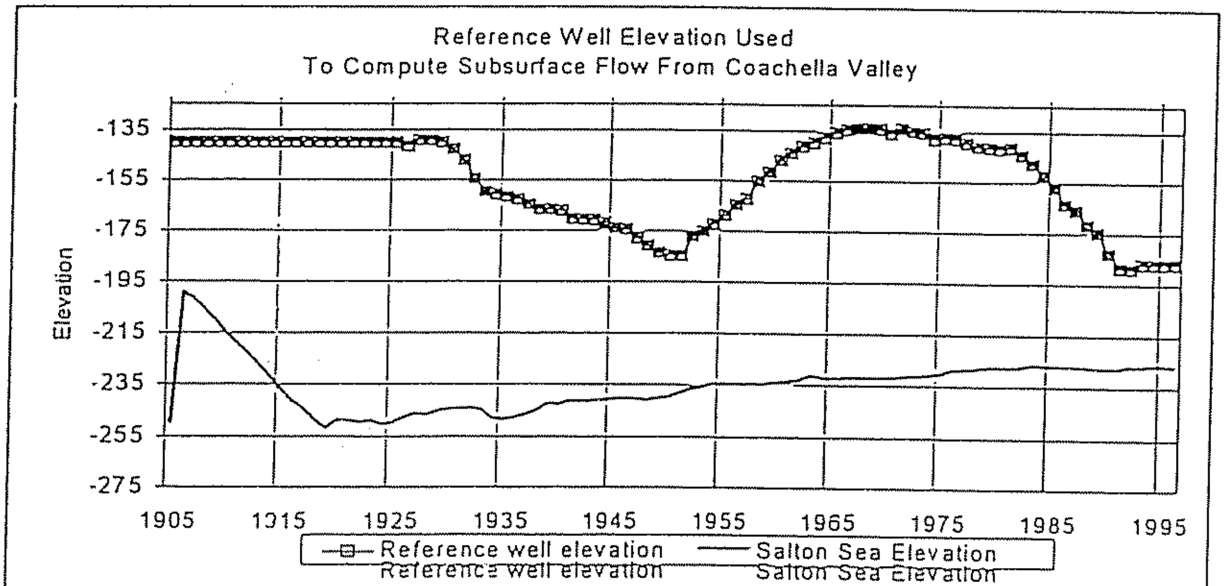


Figure II-10

wells had to be extended backward to 1926 This was done by using the average difference in elevation for the two wells which went back to 1926 and the well being extended, subtracted from the average of the two full-record wells Figure II-10 represents a graph of the elevation curve to

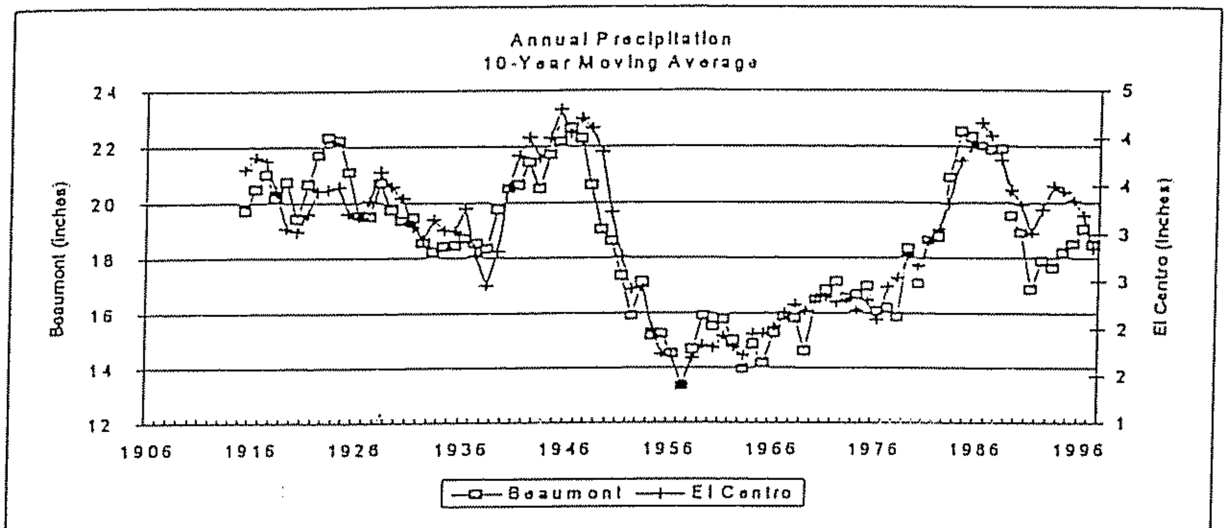


Figure II-11

be used in the model for computing subsurface flow to the Sea. Table II-2 contains the values plotted, along with the difference between the two.

Table 3 in DWR's Bulletin 108 estimated groundwater storage capacity and the amount in storage. It is reproduced on the previous page. It should be noted that there is a significant error in the table. For the "Thermal subarea, Semiperched ground water", the "ground water in storage, spring 1961, Amount stored in first 60 feet below water table" reads "374,000" acre-feet. For other numbers in the table to match, this number must be 874,000 acre-feet.

Precipitation

DWR's Bulletin 108 used three precipitation stations in its analysis, Beaumont, Indio, and Raywood Flat. The earlier Salton Sea model was originally based on the El Centro precipitation station data. Data for the Beaumont station was added to the model in an attempt to define supply by precipitation to the Coachella Valley. Figure II-11 depicts ten-year moving average precipitation for the El Centro and Beaumont stations.

Loss Of Water From the Unlined Coachella Canal

When the first forty-nine miles of the Coachella Canal were lined, a reduction in seepage loss of 130,000 acre-feet per year was assumed. The amount saved by lining should not be considered as a single value. For example, during the eight-year period 1965-1973, only 100,000 acre-feet per year was lost. The disposition of water lost prior to the lining is required for a historic calibration study of the Salton Sea. The possible destinations of the lost water include 1) consumed by native vegetation; 2) entered the groundwater basin but resurfaced to enter Imperial Irrigation District's East Highline Canal; 3) went into an increasing-in-volume groundwater mound beneath the canal; or 4) entered the Salton Sea by groundwater displacement.

Groundwater elevation contour maps were available from various sources, including

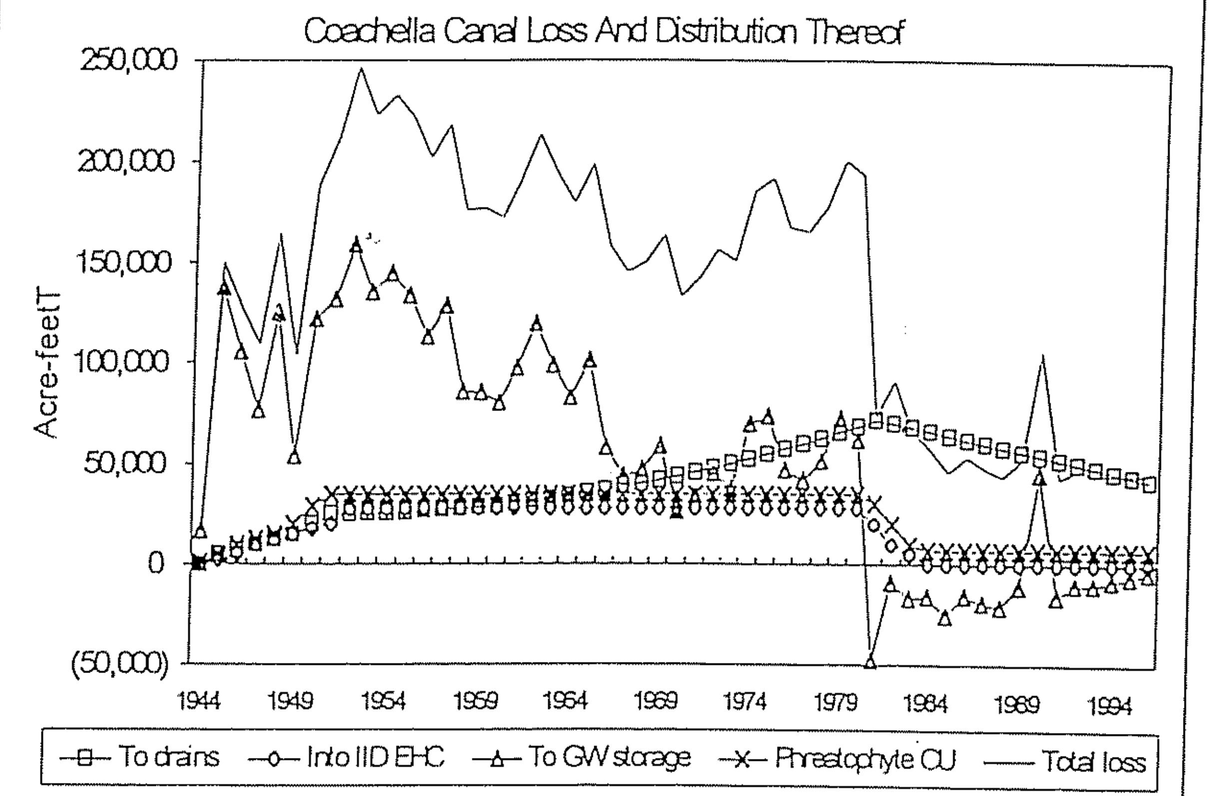


Figure II-12

CVWD (1976 plates 1-3). Water first entered the Coachella Canal, according to IID records, in 1944, and a total of 570,000 acre-feet was delivered into the canal during 1944 through 1948 before first water was delivered to CVWD users in 1949. The contour maps were used to determine the volume of the mound in 1980. Using a 30% storage coefficient, and assuming the slope of the mound was similar on both sides of the canal due to the lack of wells on the east side of the Canal, it was determined there were 3.6 million acre-feet in the mound beneath the canal before it was lined in 1980, while 4.51 million acre-feet of water was lost from the unlined first 49 miles. Figure II-12 displays the estimated disposition of water lost. A comprehensive groundwater model of the mound was beyond the scope of this study. It is doubtful whether a more accurate accounting can be made due to the lack of groundwater elevation data on the east side of the Coachella Canal

CHAPTER III
Salinity

Measured Salton Sea Salinity

Methodical measurement of salinity in the Salton Sea began in 1948. Records furnished by IID provide end-of-year salinities. When related in terms of tons of salt, the change from year to year is dramatic due, perhaps, to measuring error. Figure III-1 depicts total, as well as annual change in salt in the Sea. As can be seen, annual changes are sometimes negative. In fact, 1991, 93, 94 and 1995 all showed salt loss, an average salt loss of 9.794 million tons per year. Figure III-2 shows the results of straight-line regression of salt load in the Sea versus time. The regression yields an average of 4,483,347 tons per year added during the period 1948-1996. A one-percent error in total Sea salt measurement in 1996 would equal a salt load of 4.23 million tons.

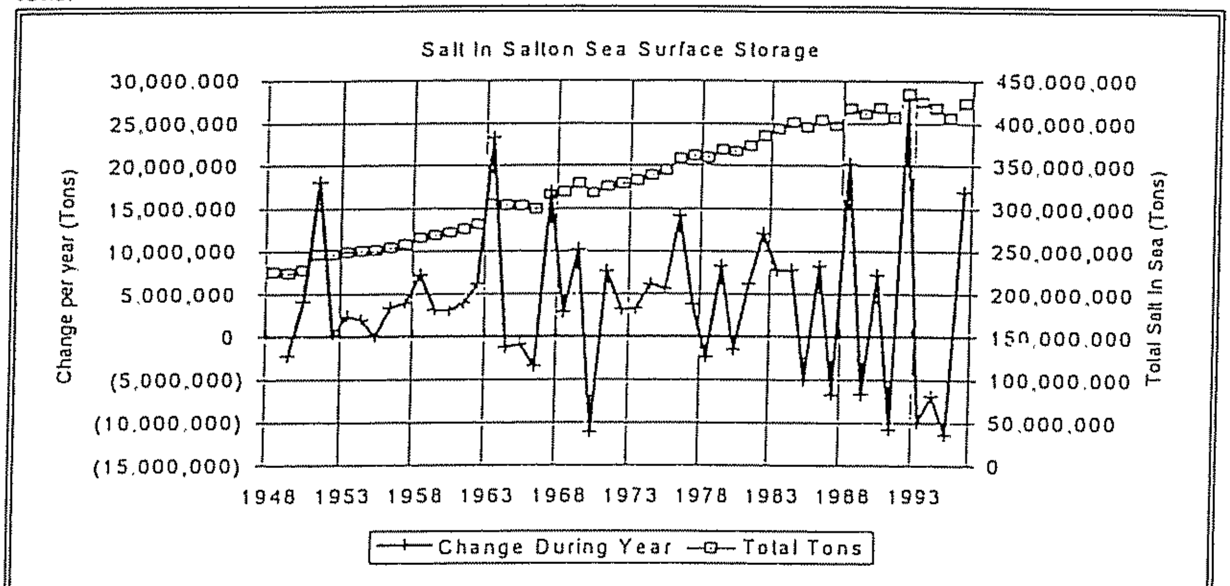


Figure III-1

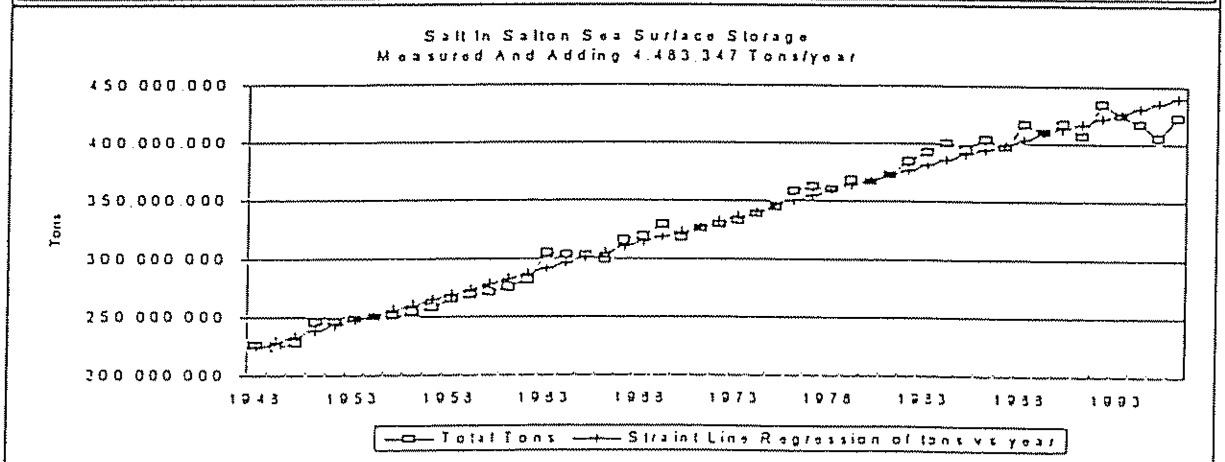


Figure III-2

<u>Salt Flow From Mexico</u>

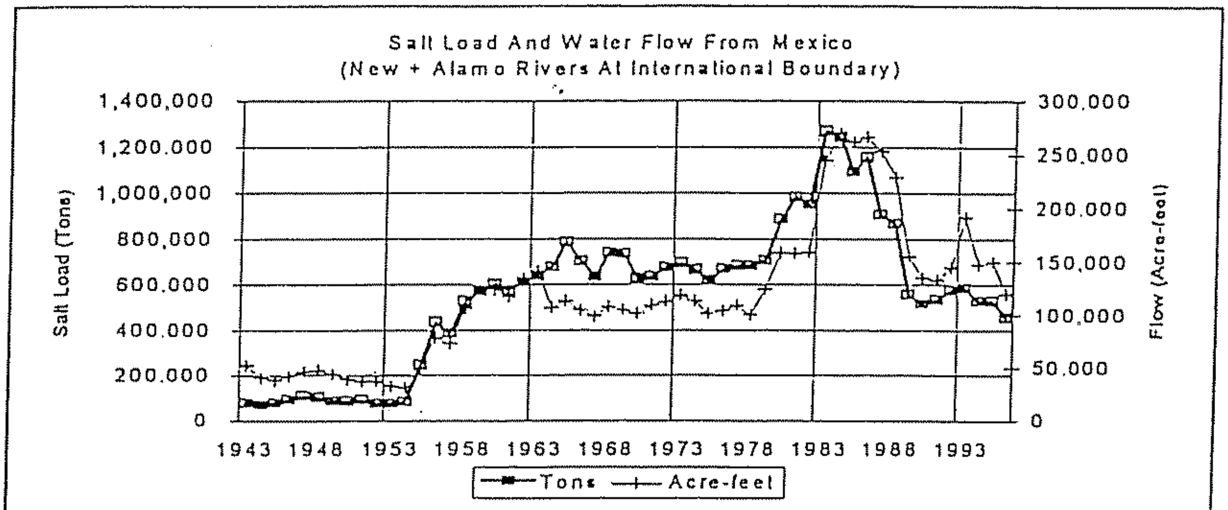


Figure III-3

Flow from Mexico is currently comprised of waters flowing in the New and Alamo Rivers. Records of the International Boundary And Water Commission (IBWC), and those of IID show average flows of the two rivers for the period 1943-1996 to be 113,559 acre-feet per year for the New River, and 3,078 acre-feet per year for the Alamo River. Average salt loads for the same period were 554,113 tons per year and 7,990 tons per year respectively. Salt loads were obtained from IID. Combined annual salt load and flow are depicted in Figure III-3. A relationship was developed for the model salt load based on annual precipitation at El Centro, as supplied by IID, and the quality of water at Morelos Dam, as supplied by IBWC. The relationship is:

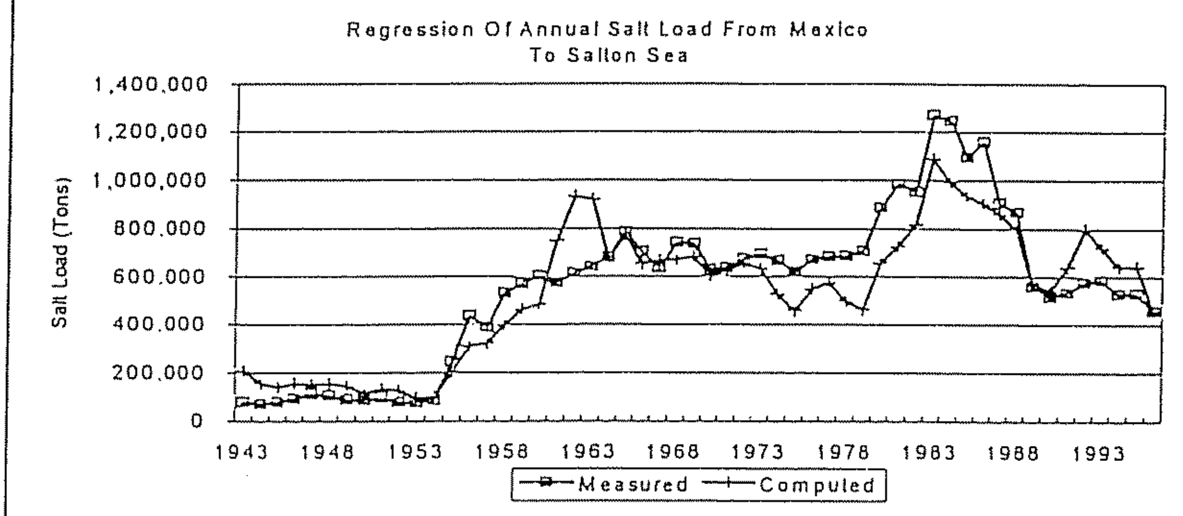


Figure III-4

Salinity (in tons/af) = -0 09889*(NIB quality in ppm) + 0 00450*(Rainfall in inches)

The R Squared value for this relationship is 0.503. Most of the variability in the quality of flow from Mexico is due to the quality of the supply water at Morelos Dam. The R Squared value for a relationship involving the ppm of Morelos Dam water only was 0.462, while a relationship involving precipitation only was 0.015. Figure III-4 depicts measured annual salt load from Mexico into the Salton Sea versus the computed values.

Salt Leached From IID Soils

IID has calculated salt load into the District at Drop #1 of the All-American Canal, and salt load out in its discharge points to the Sea in order to calculate salt gain since the year 1944, if not earlier (IID 1970). According to the 1970 IID report, more salt was entering IID than leaving until the year 1949. IID began installing tile drainage in the year 1929. By 1943, 25,120 acres had tile drainage installed. Roughly the same number of additional acres were drained each year until 1969, when a total of 354,022 acres were tile drained.

While the added drains each year finally reached a point where more salt was being removed from IID soils than was being imported, the gains were too variable, as depicted in Figure III-5, to be due to increasing drainage. The net salt gain ranged from 1,148,072 tons in 1977 to 15,635 tons in 1996. It appeared there was some mechanism other than tile drainage being added which was causing the changes in

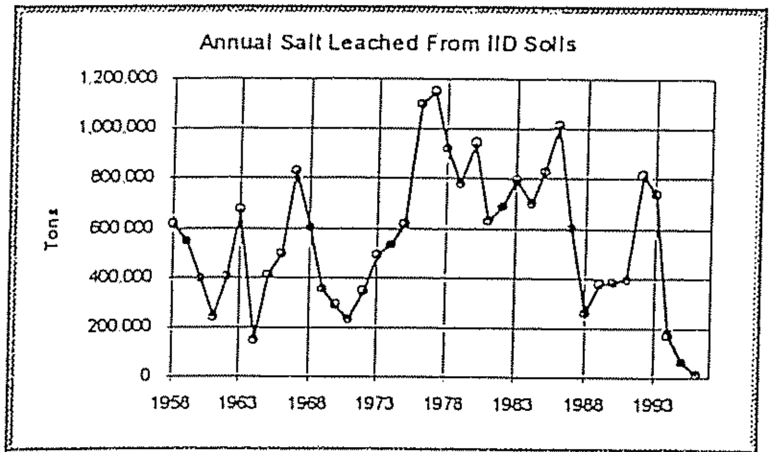


Figure III-5

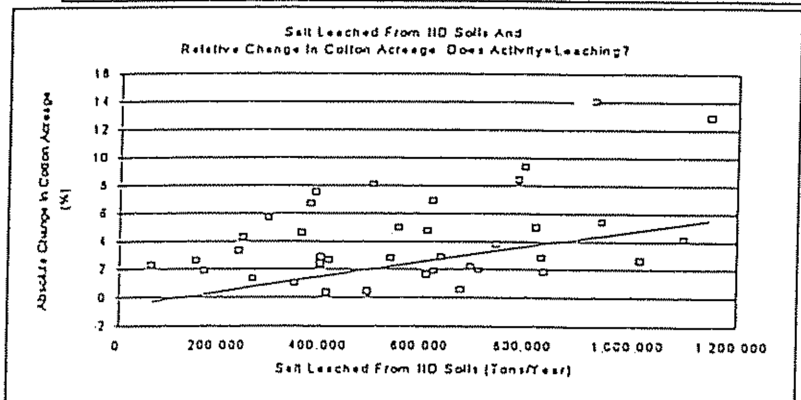


Figure III-6

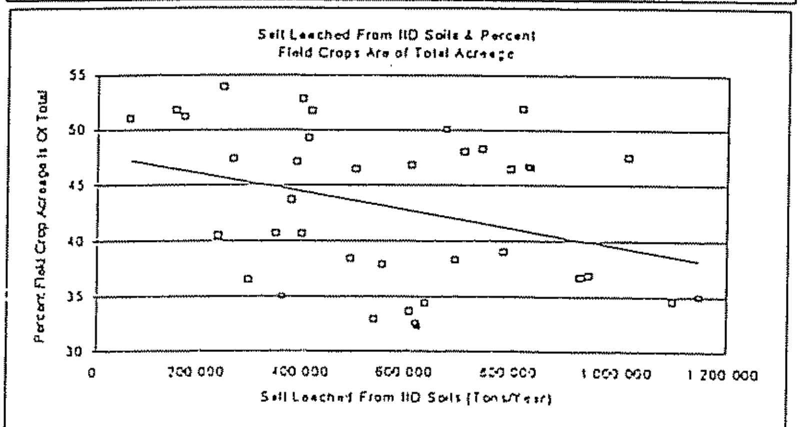


Figure III-7

net salt gain. Various possible causes for this large variability were investigated. It was first hypothesized that leaching would take place when a field's crop was changed. This was tested by summing the absolute percent change in four major crop categories from year to year and correlating this change against IID salt gain. Figure III-6 depicts the relationship between cotton acreage change and salt leached. The R Squared value for this relationship was 0.190. The R Squared for cereal and seed acreage change against salt leached was 0.158. In short, the relationships did not seem significant.

Next was tested the absolute acreage of field crops against salt leached. The hypothesis was that leaching should be less when more hay crops are planted because hay consumes water to such a degree that it is difficult to supply enough water to the crop, let alone extra water for leaching.

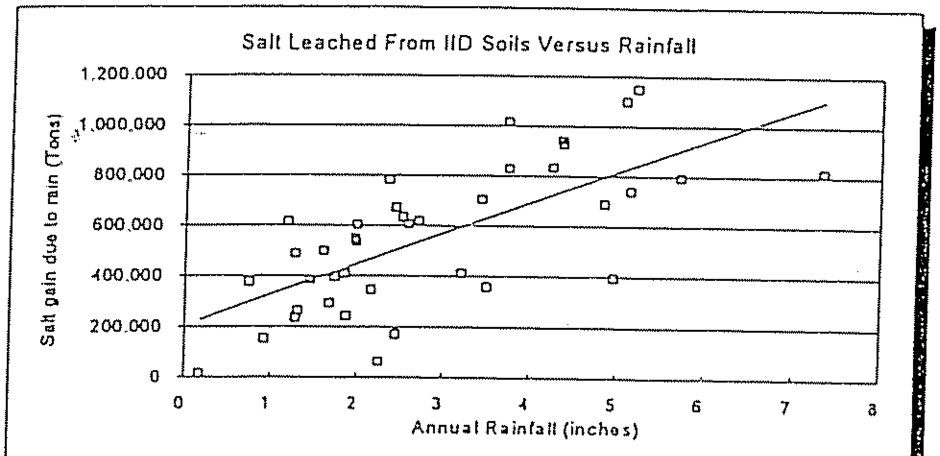


Figure III-8

Figure III-7 depicts the relationship between field crops and salt leached. The salt leached does drop as hay acreage increases, but the R Squared value for this relationship was only 0.108.

Finally, it was hypothesized that rainfall plays a role in salt leached. Annual rainfall was correlated against salt leached. This relationship is depicted in Figure III-8. The R Squared value for this relationship is 0.486, which is significant. It is interesting to note that the lowest amount of salt leached during the period 1958-1996, 15,635 tons, had the lowest rainfall during the period, 0.26 inches, and that the highest salt gain, 1,148,072 tons, had the next-to-highest rainfall, 5.21 inches. It is believed the salt is gained by infiltrating the soil and exiting later on through drains. Various studies have shown surface runoff picks up little salt. The equation for salt leached is

$$\text{Salt Leached} = 205{,}172 + 122{,}331 * \text{Rain}$$

where salt leached is in tons per year and Rain is in inches per year.

Reduced Evaporation From Sea Due To Increasing Salinity

An equation was used in previous versions of the Tostrud Salton Sea model to calculate reduced evaporation from the Salton Sea due to its increasing salinity. That equation is conditional. If the salinity of the water is 56,200 ppm or less, there is no reduction in evaporation. If the salinity is greater than 56,200 ppm, then the evaporation is reduced by the factor of the equated value at the given salinity divided by the equation's results at 56,200 ppm. The equation is:

$$P11 = 0.7136 - 3.792E{-}07 * Salinity - 7.329E{-}13 * Salinity^2$$

where salinity is in ppm. P11 at 56,200 ppm is equal to 0.689974. Figure III-9 represents the percent evaporation is decreased by at salinities greater than 56,200 ppm. Since the Sea's salinity has not yet exceeded 56,200 ppm, this equation was not used in equating historic evaporation from the Sea.

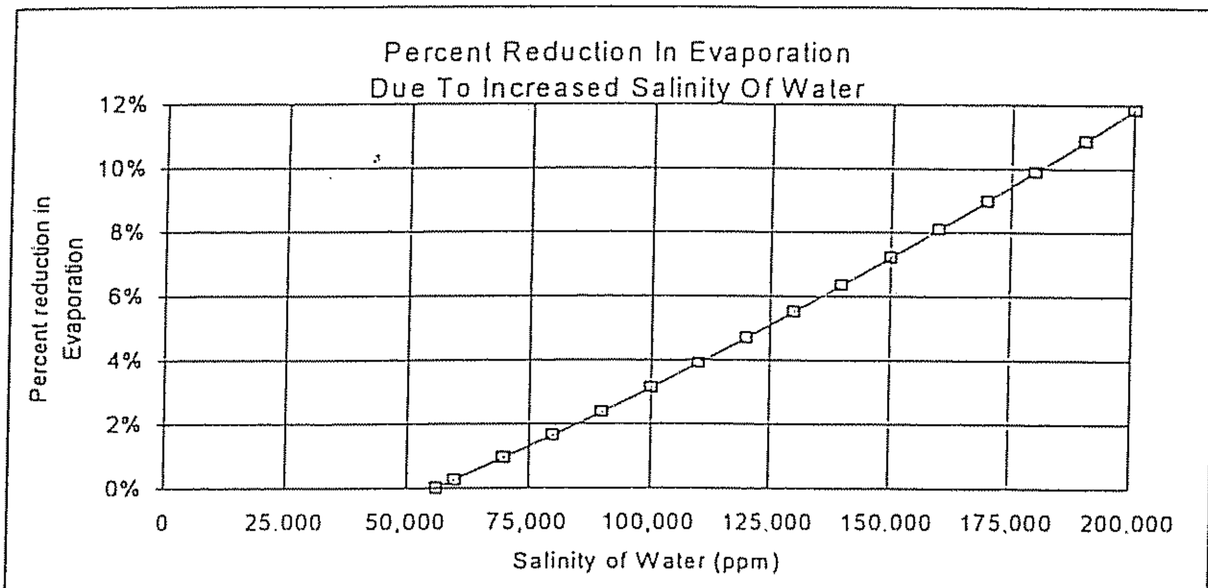


Figure III-9

Salt Constituent Balance

Because it appeared, from examination of annual salt gain in the Sea, that a drop in salt loading had taken place recently which could be explained only by precipitation of salts caused by one or more salt constituents having reached its solubility limit, a rough estimate was made of the Sea's historic salt load constituents. The period used was 1905 through 1989.

Constituent breakdown of Salton Sea water was obtained from IID for the period 1983 through 1989 in the form of twice-yearly analyses for the six major constituents. Salinity is measured twice yearly at five locations in the Sea. The calculated sum of constituents was usually considerably less than the residue evaporated at 180°C value. Salinity based on sum of constituents for the fifty-five samples collected averaged 5.9% less than salinity based on the residue method. It appears the drying results rather than the calculated sum of constituents has been the method used for reporting Salton Sea salinity.

Estimates were made of, 1) total salt constituent tonnage into the Salton Sea basin, 2) total salt constituents into the Sea, which are comprised of primarily irrigation return flow; and 3) total salt constituents in the Sea at the end of 1989. The difference between 1 and 2 would account for constituent salt gain or loss due to irrigation. The constituent breakdown of Colorado River water entering the Salton Sea basin year by year for use in this study was not rigorous. The average breakdown for the period 1941-1965 (Irelan, Table 6, page E12), on a percentage basis, was used. Each constituent percentage was multiplied by the annual average quality of water at Imperial Dam (USBR Progress Report) times flow into the Salton Sea basin to obtain constituent tonnages. Flow into the basin equaled the sum of IID and CVWD plus six times Mexico's drainage flow crossing into the United States. (Records do not exist for the location of lands on which Colorado River water has been used in Mexico. Some drainage water flows south. The quality of Mexico's return flow water is twice that of IID's and IID consumes two-thirds of what it diverts. Hence, Mexico's diversions were assumed to be six times its return flow.) For the period prior to 1941, salinities at Imperial Dam were estimated using a Tostrud model of salinity in the Colorado River Basin

The percentages of total salt load used are shown in Table III-1. Shown are two sets of percentages; 1) "→* Yearly flow", and, 2) "Used for entire period". The second column was derived by summing the tonnages of each of the six constituents for the period 1941-65 and dividing by the total tonnage of the six. The first column was derived, as a check, by multiplying the flow at Imperial Dam by the percentages in the second column. The difference between the two columns is due primarily to the fact that HCO_3 is usually at its saturation limit in Colorado River water, so that as the flow increases, the percentage of HCO_3 increases far more than that for other constituents.

Table III-1 % Constituent Makeup
Colorado River Water At Imperial Dam

	→ Yearly flow	Used for entire period
Ca	11.53%	12.28%
Mg	3.51%	3.52%
Na+K	14.32%	17.23%
HCO_3	20.33%	10.29%
SO_4	38.24%	41.22%
Cl	12.07%	15.47%
	100.00%	100.00%

A problem in reporting also exists. Bicarbonates derived in an analysis are usually multiplied by 0.492 when the constituents are summed for comparison with the salinity of a sample by the evaporation method because of the bicarbonate is converted to carbonate during the analysis (USGS Water Resources Data). Reports usually don't stipulate how the carbonates are reported. It is beyond the scope of this report to resolve in what manner bicarbonates have been reported by various authors in past studies. The difficulty is merely pointed out

Table III-2 represents the calculated total tonnage of constituents diverted from the Colorado River into the Salton Sea basin for the period 1905-1989, and what was in the Sea's surface storage at the end of 1989. As can be seen, 289 million tons of salt entered the basin from the Colorado River, while 411 million tons of salt were in the Sea at the end of 1989, or a gain of 122 million tons, equal to an average gain of 1.435 million tons per year. A large amount of salt was leached in the first few years of the Sea's formation, primarily sodium chloride. IID has estimated that there were 77 million tons of salt in the Sea in 1907, and 110 million tons by 1914. By 1907, 22 million tons had come from the Colorado River, and by 1914, a total of 30 million

Table III-2 Using sum of flows IID+CVWD+Mexico from Colorado River times % constituents for 1961-1965, tons from Colorado versus what is in Salton Sea

	1905-89 enters Sea basin (tons)	1983-89 avg Sea const (ppm)	In Sea End 1989 (tons)	In Sea minus into Sea (tons)	Into Sea/ In Sea
Ca	35,531,481	1,102	10,680,908	-24,850,573	3.33
Mg	10,172,319	1,608	15,585,209	+5,412,890	0.65
Na+K	49,858,690	12,200	118,245,987	+68,387,296	0.42
HCO_3	29,764,779	247	2,393,997	-27,370,782	12.43
SO_4	119,274,022	9,050	87,715,261	-31,558,762	1.36
Cl	44,772,531	18,235	176,738,981	+131,966,450	0.25
	289,373,822 tons from Colorado R.		411,360,341 In Sea	+121,986,519 Difference	
				1,435,136 tons/year came from elsewhere	
	end of 1989 =	7,126,687 af in Sea at 42,327 ppm			

tons had come from the Colorado River. Using these numbers, 55 million tons of sodium chloride had dissolved from the Sea floor by 1907, and 80 million tons by 1914.

It can also be seen that the salinity makeup, when comparing Colorado River water with Salton Sea water, shows a considerable change. There is less than one-third as much calcium in the Sea as entered from the Colorado, and only one-twelfth the bicarbonates. There is four times as much chloride in the Sea as came from the Colorado, and roughly double the magnesium and sodium plus potassium. The calcium, bicarbonates, and sulfates have precipitated out to a degree. While an exhaustive year-by-year analysis of return flow constituents from irrigation sources was beyond the scope of this report, Table III-3 contains limited constituent data obtained from IID reports for the years 1962, 64, 66, and 69 (from published IID reports), and 1996. CVWD return flows were not considered, due to the lack of data from CVWD. The table also includes constituent quality data on the Colorado River at Imperial Dam

Table III-3 Limited Return Flow Water Quality Data (ppm)

	Ca	Mg	Na+K	HCO3	SO4	Cl
IID Out flow	184	110	623	223	794	894
1961-65 Colorado River At Imperial Dam	99	28	139	165	333	125

Table III-4 is a constituent balance for IID based on the four years 1962, 64, 66, and

1969. It appears, from Table III-4, that roughly a quarter of the calcium entering IID precipitates in soils. Magnesium and sodium plus potassium appear to be leached from IID soils (10% and 49% increase, respectively). HCO_3 appears to be cut in half by precipitation in IID soils. Sulfate seems to remain roughly in balance before entering the Sea (a 16% drop). Chloride tonnage leaving IID is about double that entering.

Table III-4 Representative Annual Salt Tonnage Balance For IID

		Tons to IID from Col Riv	Tons out of IID	Out Minus In	% change
Ca	tons	386,000	280,000	(106,000)	-26%
Mg	tons	130,000	142,000	12,000	+10%
Na+K	tons	542,000	812,000	270,000	+49%
HCO_3	tons	352,000	169,000	(183,000)	-51%
SO_4	tons	1,275,000	1,109,000	(165,000)	-16%
Cl	tons	539,000	1,132,000	594,000	+112%

(For years 1962, 64, 66 and 69.)

It should be pointed out that anion and cation summations usually don't match perfectly due to analytical inaccuracy. For the analyses by IID just presented, the cations were 9.75% less than the anions for inflow, while the cations were 0.53% greater than the anions for the outflow. Theoretically, anions, expressed in mole equivalents, must match cations. The Na+K molecular weight assumed, based on analysis of a number of samples was 23.60. Sodium has an atomic weight of 22.99, while potassium's is 39.10, meaning most of the Na+K is sodium.

It should be noted also that a constituent change may not be absolute. For example, an exchange may go on between dolomite ($CaMg(CO_3)_2$, gypsum ($CaSO_4 \cdot 2H_2O$), and calcite ($CaCO_3$). This is described by Hem (1985, p. 200). "Water that moves for long distances through impure limestone and dolomite may participate in irreversible processes. Calcite saturation may be reached first, after which gypsum and dolomite continue to dissolve along the flow path while calcite is precipitated (Plummer and Back, 1980)." The chemistry of dissolved solids is very complex. There are many factors which determine any salt's solubility limit, including water temperature, pH, CO_2 partial pressure (which is influenced greatly by the presence of biological activity), and the amount of other salts present.

Change In Sea Salt Load Due To Solubility Limits Being Reached

As stated earlier, it became apparent during this study that a reduction in the Sea's annual salt load gain seems to have taken place. The drop seems to have started in approximately 1980. The model's salinity began going up faster than the Sea's measured salinity. Up to that point in study time, precipitation of salts in the Sea had not been analyzed, though it was known bicarbonates and calcium were undoubtedly precipitating. But, in order to determine if any constituent salt had reached its solubility limit, estimates of each constituent entering the Sea from the time of its original formation were needed. Hence, an attempt was made to estimate total constituents entering the Salton Sea basin, the amounts gained or lost due to irrigation, thereby the salts entering the Sea, and the amounts in the Sea. A comparison of the total historic amount of each constituent entering the Sea through the year 1989 against what was in the Sea in 1989 would help identify if any solubility limit had been reached.

The constituent loads into the Salton Sea basin from the Colorado River were explained above. The salts which actually entered the Sea from primarily irrigation return flow, in constituents, were derived using the following salinities; Ca=174 ppm; Mg=110 ppm; Na+K=593 ppm; HCO_3=217 ppm; SO_4=785 ppm, and, Cl=790 ppm. These values are somewhat different from those presented in Table III-3. The values used for the long term, just listed, were derived by analyzing individual IID return flow samples and removing apparent outlying data which would unduly influence the average, and to choose constituent values whereby the sum of anions would match the sum of cations. Each constituent load in the Sea at the end of 1989, as found in Table III-2, was used as the level for saturation, if saturation had been reached.

Following are graphs for each of the six constituents showing the amount in the Sea at the end of 1989, and the cumulative amounts into the Salton Sea basin, and into the Salton Sea. The difference between the into-the-basin and the into-the-Sea amounts is primarily due to leaching or precipitation of salt in irrigated soils. The sodium and chloride graphs have been adjusted to show the initial large dissolution of sodium chloride during the present Sea's original formation.

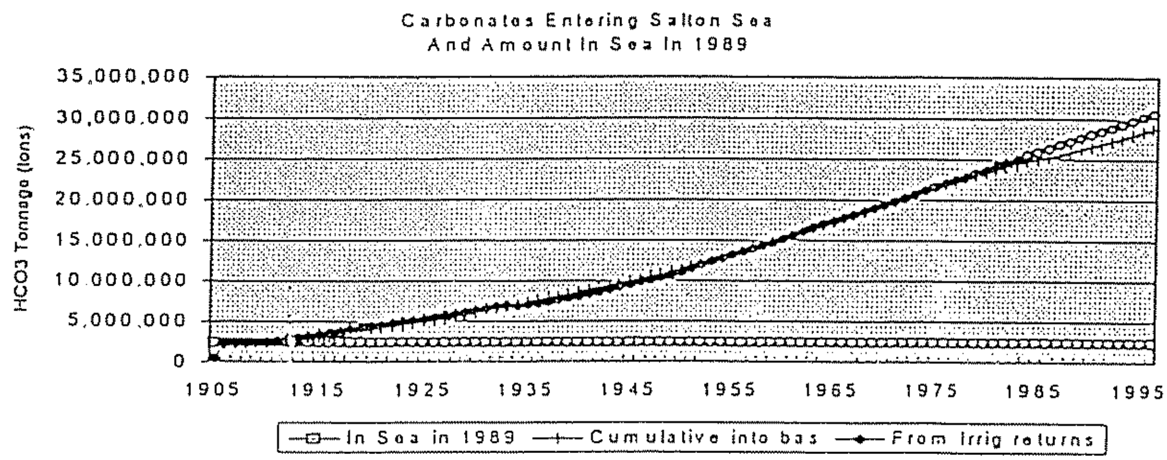


Figure III-10

Figure III-10 shows that bicarbonate saturation occurred in almost the first year the Sea was formed. An examination of bicarbonate data for the Colorado River shows bicarbonate tonnage decreases as the river flows toward Imperial Dam from Lake Powell in order to maintain a relatively constant bicarbonate concentration.

As can be seen from Figure III-11, calcium saturation in the Sea appears to have taken place in roughly 1950.

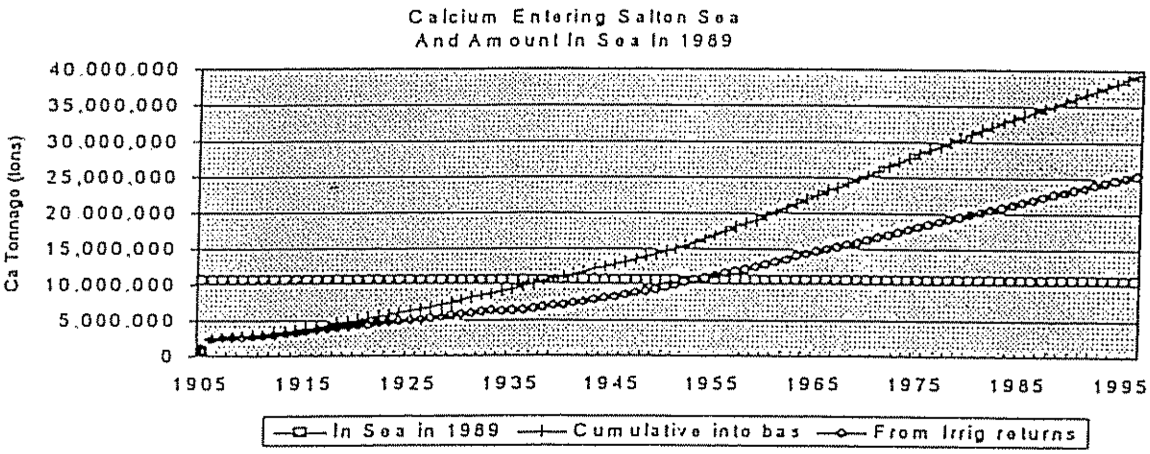


Figure III-11

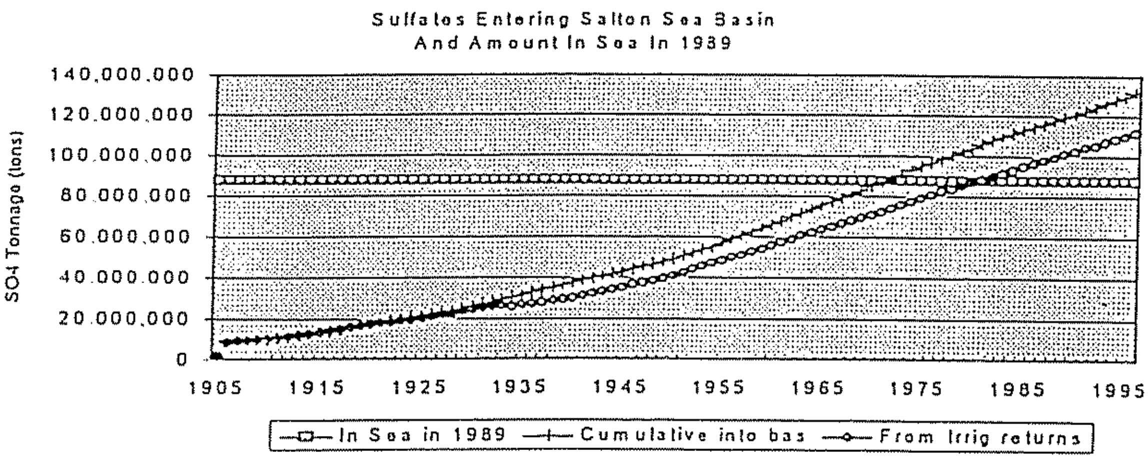


Figure III-12

From Figure III-12, it appears as though sulfate reduction should have begun in about 1980. The solubility limit for sulfate is, perhaps, one of the most difficult to determine. Hem (1985, page 101) discusses sodium sulfate levels.

"Sodium sulfate solubility is strongly influenced by temperature. The solid precipitated may contain various amounts of water, ranging from mirabilite or Glauber's salt with the formula $Na_2SO_4 \cdot 10H_2O$, through the heptahydate with seven molecules of water and the anhydrous form. Closed-basin lakes in cool climates may be redissolved at higher temperatures. Mitten and others (1968) discribed (sic) such effects in eastern Stump Lake, N. Dak. Sodium concentrations in the lake during a 5-year period of intermittent sampling generally were between 20,000 and 30,000 ppm. An apparent decrease of about 25 percent in sodium concentration and a corresponding loss of sulfate was reported over a 1-week period when the water temperature decreased from 11° to 3°C (Mitten and others, 1968, p. 26). Somewhat similar deposition of mirabilite has been observed in Great Salt Lake, Utah (Eardley, 1938)."

Table III-5 Comparison of Sea Water and Salton Sea Water in 1989 (ppm)

	Sea Water	Salton Sea
Ca	410	1,100
Mg	1,350	1,608
Na+K	10,890	12,200
HCO_3	142	247
SO_4	2,700	9,050
Cl	19,000	18,235

A comparison of the makeup of seawater (Hem, 1985, p. 7) and Salton Sea water in 1989 is shown in Table III-5. As can be seen, the constituent which is significantly different from ocean water is sulfate, being nearly four times that of ocean water. Hence, it would not be illogical to assume the solubility limit for SO_4 had been reached.

Table III-6 Computing Needed Cations To Precipitate Sulfate Since Solubility In Salton Sea Apparently Reached In 1980

SO_4 precipitated since 1980	1,503,995	tons/year
Ca precipitated in Sea since 1980 =	342,320	tons/year
HCO_3 precipitated in Sea since 1980	426,075	tons/year
Ca needed to precipitate above HCO_3	279,879	tons/year
Adjusted drop in irrigation precipitation of Ca due to insufficient cations for precipitation in soils a/	251,821	tons/year
Ca left over for $CaSO_4 \cdot H_2O$ (gypsum) formation	324,262	tons/year
Cl gained in Sea since 1980	500,000	tons/year
Above would have provided Na, from NaCl =	332,835	tons/year
Na calculated gain in Sea since 1980 =	210,510	tons/year
Na left over to precipitate SO_4	122,325	tons/year
Mg average gained in Sea = 23,516 tons/yr, but assumed to be from Mg_2SiO_4		
Amount of SO_4 in Na_2SO_4 precipitated by above Na	248,952	tons/year
Amount of SO_4 in $CaSO_4$ precipitated by leftover Ca	777,161	tons/year
Total SO_4 precip. combined with Ca or Na	1,026,114	tons/year
SO4 precipitated since 1980 according to graphs	1,503,995	tons/year
Error, or combined with other anions	477,881	tons/year
Total precipitation of Ca, SO_4, and Na	1,496,217	tons/year

a/ Graphs showed 174,071 tons/year of Ca precipitated in soils, requiring 417,196 tons/year of SO4 to precipitate the Ca, but there were only 192,932 tons/year of SO4 precipitated in soils according to graphs, so Ca precipitation in soils was reduced

A cursory examination of the graphs shows that sulfates could have begun combining with sodium around 1980 to precipitate out in one of the $Na_2SO_4 \cdot \_\_H_2O$ forms Hem describes, and as $CaSO_4$. It would be very difficult to determine the reaction taking place. Sodium chloride dissolving would provide the sodium needed for combination with sulfates, and excess calcium would be available if it hadn't formed calcium carbonate. A constituent balance was calculated assuming sulfate reached its saturation limit in the year 1980. Table III-6 presents the results. As indicated, if sulfate began precipitating in 1980, it would precipitate in primarily two forms, $CaSO_4$ and $Na_2SO_4 \bullet \_H_2O$. A balance, as the table shows, was run to determine 1) the amount of Na provided by the dissolution of NaCl in the Sea, with the difference between how much Na there should have been to how much there was gained equaling the amount of Na precipitated; 2) the amount of Ca which would have used HCO_3 to precipitate out calcite, hence, the amount left to form $CaSO_4$; 3) the amount of SO_4 which would have combined with the remaining Ca to precipitate $CaSO_4$; and, finally, 4) the amount of SO_4 which would have combined with Na. The amount of calcium precipitating out in irrigated soils appeared to be too high. There was not enough SO_4 or HCO_3 reduction in irrigated soils to account for such a large drop of calcium in the irrigation soils. Therefore, this calcium was added to the amount in the Sea available for precipitation.

As can be seen from Table III-6, 1.504 million tons of sulfate per year precipitated since 1980 if only the sulfate graph is used, while only 1.026 million tons of sulfate were precipitated due to combination with calcium and sulfate. The total tonnage of sulfate, calcium, and sodium which combined to precipitate appears to have been 1.469 million tons per year from 1980 through 1996.

As an independent check, the Sea's total annual salt gain was equated by using regression of total salt in the Sea against time for two periods, 1948-1979, and 1980-1996. For the first period, the Sea gained 4.645 million tons per year, while for the second period, the Sea gained 3.076 million tons per year, or a drop of 1.569 million tons per year. This compares favorably with the 1.469 million ton per year value derived by the first method described above.

This finding, if accurate, is quite significant. A drop in salt gain of 1.5 million tons annually is a drop of close to one-third of the Sea's annual salt load gain. The precipitation of sulfates, sodium, and calcium requires considerably more analysis due to its possible effects on the Salton Sea's future. If, indeed, 1.5 million tons per year of salt did begin precipitating fifteen or so years ago, the salinity of the Sea will rise considerably more slowly in the future than if the long-term average gain is used to predict the future. Also, if a dike is constructed in the Sea to create one fresher body of water and one more saline body, it is possible, depending on the target fresh-side salinity, that the sulfates would not precipitate out. In this case, the salinity of the fresh side of the Sea would fall more slowly than expected. This matter requires further investigation.

Figure III-14 depicts the magnesium load. It would appear as though magnesium had not reached its saturation limit in 1989, and that small, close to equal amounts of magnesium are being leached from both irrigated soils and from the Sea. Dolomite dissolution could be the source of this magnesium. Or, it could be coming from magnesite ($CaCO_3$). Magnesium was not included in Table III-6 due to its apparent small amount, and the uncertainty of its source.

Figure III-13 depicts sodium plus potassium levels. There seems to have been a gain of sodium in both irrigation soils and in the Sea.

Figure III-14 depicts magnesium loads in the Sea, and Figure III-15 depicts chloride loads in the Sea. As with sodium, chloride appears to have been dissolved from both irrigation land and from the Sea's bed.

Table III-7 depicts the average annual tonnages of the major constituents entering the Salton Sea basin from the Colorado River for the period 1975-1996.

As has been stated several times herein, constituent makeup analysis has not been rigorous. Only partial periods of records have been used in many instances. That shortcoming may pale, however, in comparison to other factors affecting constituent makeup. For example, Hem (1985, p 116)

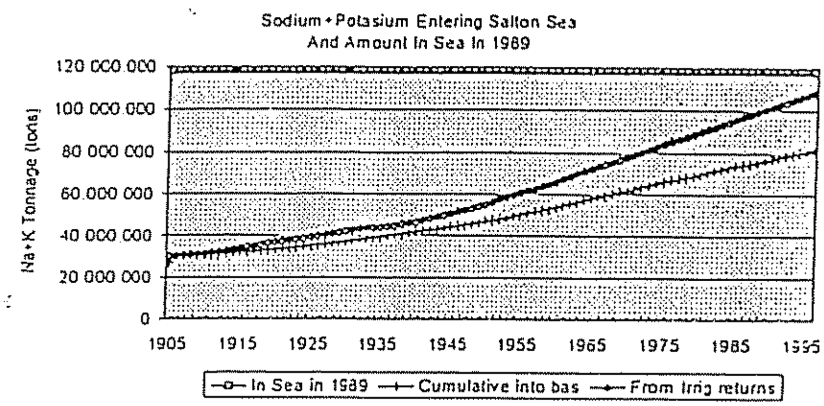


Figure III-13

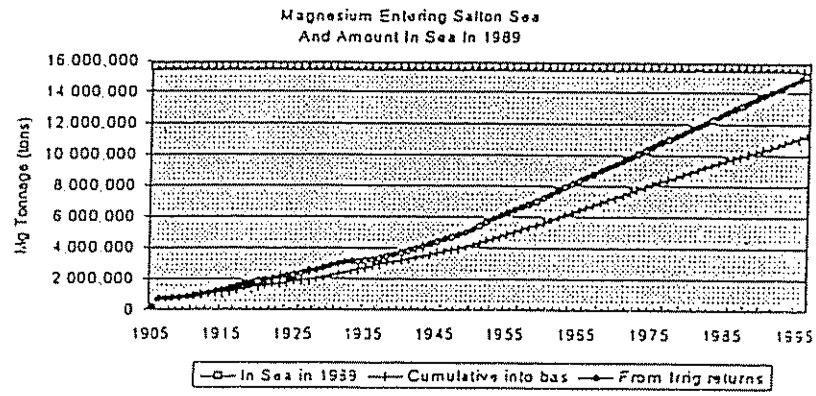


Figure III-14

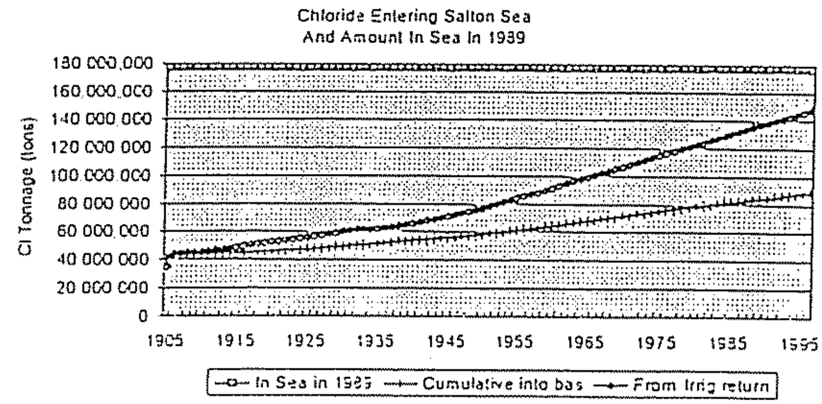


Figure III-15

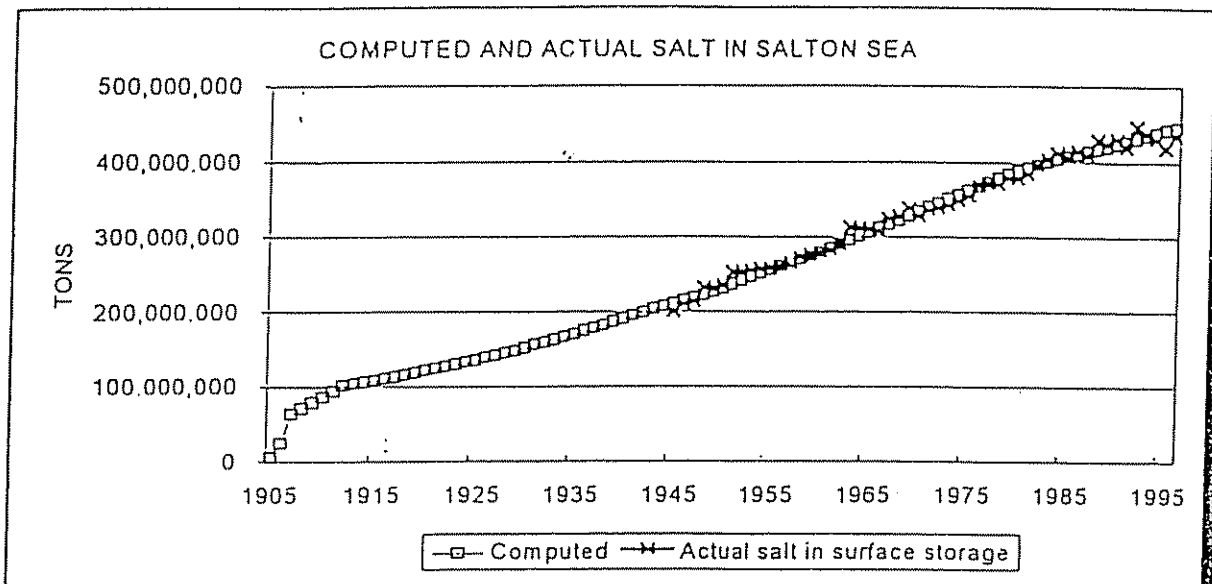


Figure III-16

discusses the solubility of Ca+SO_4 in reference to the amount of Na+Cl in the solution. The amount of Ca+SO_4 a water can hold increases as the amount of Na+Cl in the water increases, but the increased amount of Ca+SO_4 the water can hold decreases until an apparent limit is reached. (Unfortunately, the Na+Cl concentrations Hem discusses are well below those found in the Sea at present, making it impossible to determine a solubility limit for Ca÷Ca+SO_4.) There are many other factors affecting solubility limits, such as temperature and pH, which are available in IID's records. It is probable that far more detailed data could be obtained for constituent salt balance, at least in the later years of the Sea's existence, because IID has a wealth of data, though some of it would need to be placed in a format usable by computers. It is doubtful, however, if a computer model for determining solubility limits exists which is detailed enough to take into account the large amount of data available. It should also be pointed out that the sulfate solubility limit reached, apparently, in 1980, should be considered as a solution limit in ppm rather than as a tonnage limit. Were the Sea to suddenly experience a large drop in inflow, for example due, perhaps, to conservation, it is probable that a large amount of sulfate in one or more forms would precipitate, meaning the salinity would not increase as much as expected.

Figure III-16 depicts measured tons of salt in the Sea and those derived by the model. Model salt load was calculated by:

+ IID import of Colorado River at Colorado River quality at Imperial Dam
+ CVWD surface drainage flow at 2,500 ppm
+ CVWD groundwater flow at 400 ppm
+ CVWD surface flood flow at 200 ppm
+ Mexico return flow crossing boundary times Mexico's return flow quality

+ IID salt pick up due to rainfall on farm soils, as discussed earlier herein

+ 1.0 million tons/year of sodium chloride dissolution since 1906, not including NaCl dissolved when the Sea was first formed

- an average of 0.615 million tons/year from 1913 through 1948 kept in IID soils due to insufficient drain capacity to maintain salt balance. This salt was 1.1 million tons in 1913, and was reduced linearly by 30,000 tons/year. Following 1948, it was assumed IID was in salt balance, and that the excess salt in IID's salt balance came from rainfall.

- 0.9 million tons/year of Calcium salts (precipitated) beginning in 1955

- 1.35 million tons/year of sulfate salts (precipitated) beginning in 1981

For reference, the relative solubility of salts in distilled water, as taken from Langbein (1961, p. 13) is presented in Table III-8.

Table III-7 Average Salts From Colorado River To Salton Sea Basin

	Tons/Year
Ca	422,475
Mg	120,951
Na+K	592,828
HCO3	353,908
SO4	1,418,188
Cl	532353

Table III-8 Relative solubilities of salts in distilled water (NaCl=1.0 at 50°F)

Na	0.4	0.3	1.0
Mg	0.0004	0.9	1.3
Ca	0.00005	0.006	1.5
	CO_3	SO_4	Cl

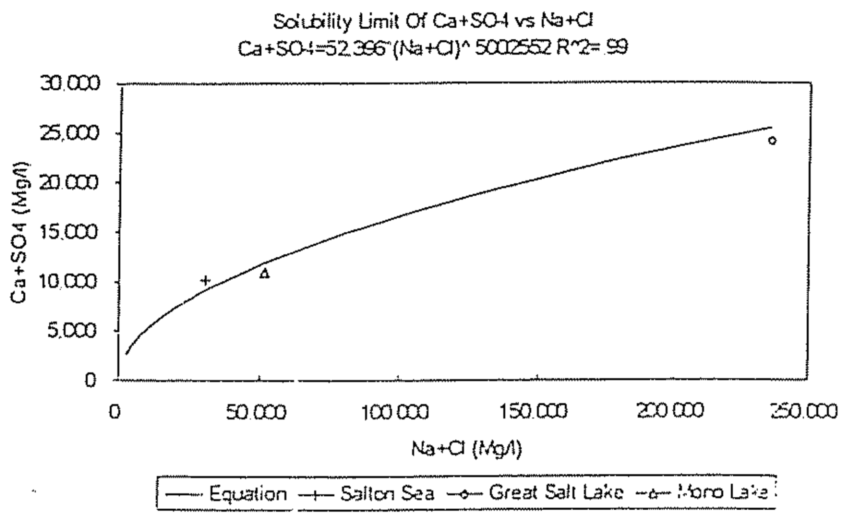


Figure III-17

Figure III-17 shows the concentration of $Ca+SO_4$ against the concentration of Na+Cl for three sites, the Salton Sea, Mono Lake, and the Great Salt Lake. It can be seen that there is not one sulfate solubility limit, but that the limit, as discussed by Hem, depends on the Na+Cl concentration, and is roughly proportionate to the square root of the Na+Cl concentration. As the concentration of Na+Cl in the Sea increases, the solubility limit of sulfate salts will increase as roughly the square root thereof. The dependance of sulfate salt precipitation on the concentration of Na+Cl was not included in the model discussed in this chapter, though the concentrations of Na+Cl and Ca+SO_4 were estimated to make sure the solubility limit, as described by the above equation, was not erroneous. The results of this test are shown in Figure III-18. The solubility line in Figure III-18 is well below the Ca+SO_4 line until roughly 1970, from which point in time onward, the two lines roughly coincide. During this period, precipitation could have been taking place on and off. Again, this analysis was based on very limited data, but it tends to corroborate the findings by two other means earlier in this chapter that sulfate salt precipitation has begun. Following 1980, there appear to have been larger than historic drops and rises in total salt in the Sea. This could be due, in part, to actual increases or decreases in salt in the Sea due to factors such as temperature or pH change, as described by Hem earlier in this chapter. As discussed earlier, a set amount, 1,350,000 tons per year, was assigned in this report to the amount of sulfate salts precipitating following 1979. This is an average only. There could have been years when no salts precipitated, and years when far more than 1,350,000 tons precipitated. As shown in Table III-7, the tons of SO_4+Ca entering the Salton Sea basin are approximately 1.65 times the amount of Na+Cl. It was the initial large leaching of Na+Cl, when the Sea first filled, together with leaching of Na+Cl from irrigation soils and from the Sea as it refilled, together with the preciptation of Ca in irrigated soils, which permitted the solubility limit of Ca+SO_4 to not be reached until recently. Also, the conservation programs by IID and IID/MWD reduced the relative amount of water flowing into the Sea, thereby increasing the Na+Cl concentration, and thereby helping to reach the solubility limit earlier.

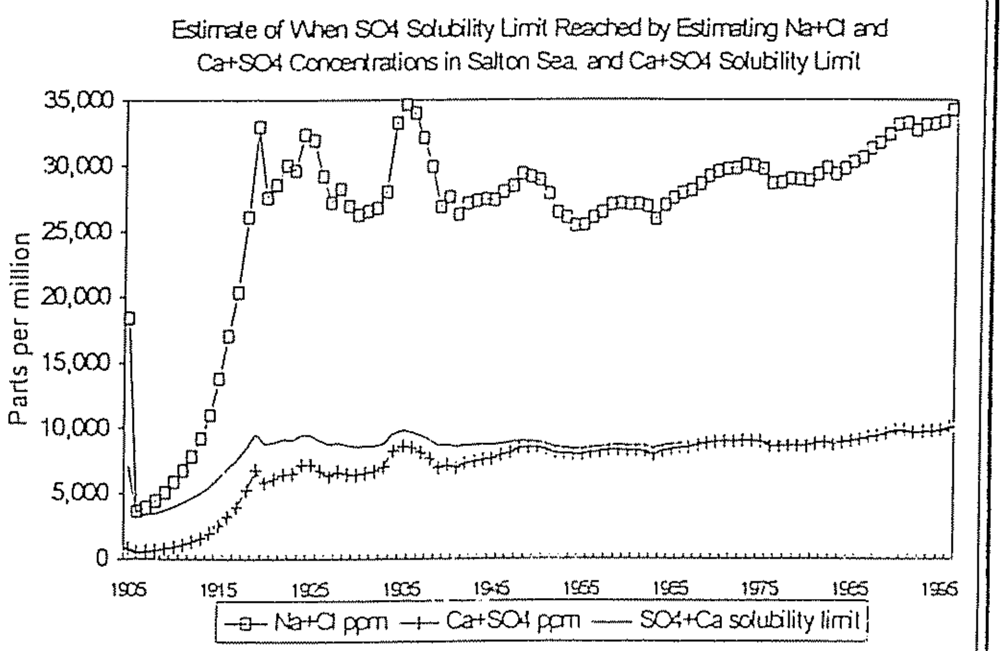


Figure III-18

CHAPTER IV
Results Graphed, and Model Constants

Calculated historic Salton Sea elevations and salinities will be presented graphically in this chapter, along with a summary of the constants used to develop them. The figures depicted are:

Figure IV-2 ... Salton Sea elevations from 1906 through 1996.
Figure IV-3 ... Salton Sea salinities from 1906 through 1996, with measured salinities not available until 1946.
Figure IV-4 ... Salton Sea elevations from 1946 through 1996.
Figure IV-5 ... Salton Sea salinities from 1946 through 1996.
Figure IV-6 ... Salton Sea elevations, 1906 through 1996, had there been a ten-percent inaccuracy in measurement of IID flow into the Salton Sea basin.
Figure IV-7 .... Relative source of water entering Salton Sea

Discussion

From 1948 onward, there is acceptable agreement between the measured and computed elevations and salinities. Prior to 1948, there are a number of factors which cause the computed elevations to differ from the measured. The two primary factors are reported acreage and reported diversions. IID, during its operation of the Alamo Canal, delivered water to land in the Republic of Mexico. Concerning acreage reporting problems, for example, an IID tabulation of historic acreages in Mexico, said of the year 1940, "The winter crop report of 1940-41 missed a large acreage in transition from winter grains to cotton. Probably the acreage should have exceeded 190,000." Only 131,000 acres were reported. Of the year 1943, the report says of Mexican acreage, "This is an estimate based on known water duty on selected lands. At the time the crop report was being taken, the farmers knew a shortage was imminent and padded their reports in expectation of proration based on acreage farmed. They reported 301,718 acres which is obviously false." IID reduced the acreage to 200,000 acres. The same crop report, for the year 1948, says, "This figure possibly is too low due to the transition from winter grains to cotton, and probable unreported acreage in the 1948 extension of the Commission Canal System."

While acreages within IID may not have suffered the same degree of reporting problems, the above quotations are examples of possible problems in any irrigation system, especially one in its formative years. There are also water flow measuring inaccuracies in any irrigation system. Improvements in technology and equipment have taken place over the years. Of deliveries to IID farms through the year 1941, an IID table says, "Note: Deliveries to land based on orifice measurement and are at least 10% less than actual as shown by tests."

Figure IV-6 shows what Sea elevations would have been if diversions into the Salton Sea basin had been ten-percent greater than measured, with all else kept constant. This represents an estimate of a 10% gaging error. From an examination of Figure IV-6, the period which has the most unexplained deviation seems to be 1937 through 1941. The Sea, in actuality, rose

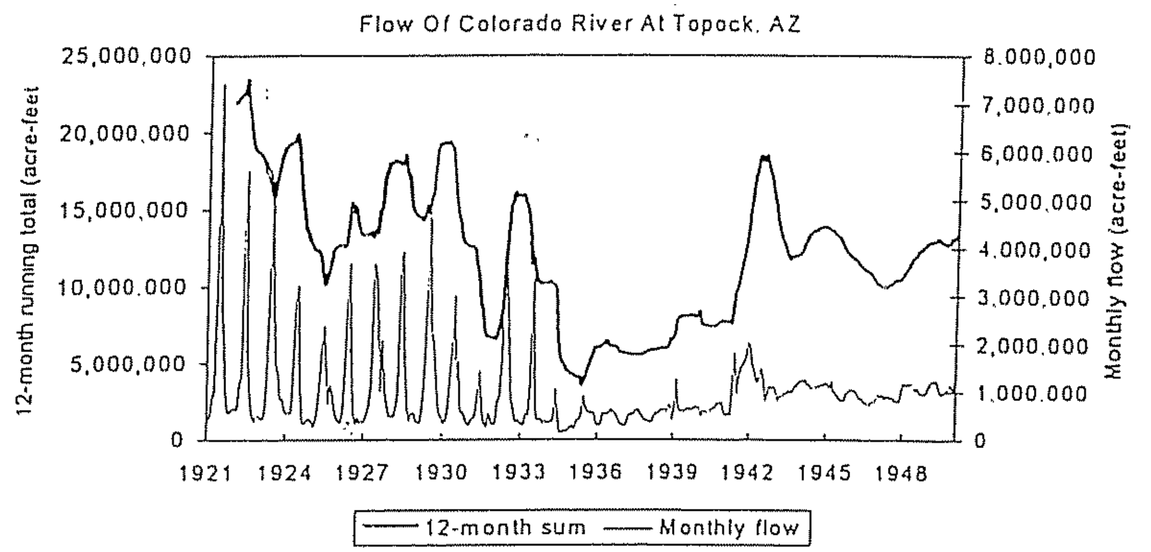


Figure IV-1

significantly in elevation, while the computed elevation stayed fairly level. This was the period following the great drought. It was also the first time water was available on a reliable basis due to the construction and filling of Hoover Dam and Lake Mead. Figure IV-1 shows monthly flow and twelve-month running summation of the Colorado River at Topock, Arizona. (Other stations along the River did not exist until the completion of Hoover Dam.) The flow record shows a dramatic change following complete regulation of the River by Hoover Dam beginning on February 1, 1935. It can be seen that, from closure through 1940, monthly releases were not much greater than unregulated low flows, so if anything, it would appear that IID certainly didn't receive more water than needed. Hence, the unexpected rise cannot be due to extra water being available. The Sea, as measured, rose during the period 1937 through 1941, by 238,000 acre-feet per year, while the computed rise was only 139,000 acre-feet per year. Computed consumption of water by crops during the period was approximately 1.5 million acre-feet per year. The cause for the unexpected rise could have been rainfall. Rainfall in Imperial Valley averaged 5.11 inches during the period. There have been only two wetter five-year periods. In 1939, 1940, and 1941, 8.52, 5.07 and 6.62 inches of rain fell, respectively. These rains undoubtedly caused severe crop damage, such that the computed crop consumption was most probably much higher than actual. This would explain why the Sea rose so much more than the computed rise during the period 1937 through 1941.

As can be seen from Figure IV-3, there have been approximately seven years in which the salinity of the Salton Sea was greater than at present. Again, it was during the drought years when the salinity, as calculated, was approximately 45,000 to 50,000 ppm. Since there were no systematic measurements of Sea salinity until 1948, these early calculated values cannot be verified. Though no search of historic records was performed, there appears to have been no bird or fish kills in the 1930s, so it might be postulated that something other than salinity level is the cause of the current problem with die-offs It is probable that selenium levels were as high during the early period as they are today also A search of Imperial and Coachella Valley newspapers for that period might resolve (only in the affirmative) whether die-offs took place

Figure IV-7 depicts the relative computed sources of water entering the Salton Sea from the Imperial Valley, the Coachella Valley, and from Mexico. While IID has always been the major source of water to the Sea, it can be seen that its contribution to the Sea has been as low as 64% in several recent years when the District was able to order water from Pilot Knob rather than from Parker Dam due to flooding on the Colorado River.

Table IV-1 lists the constants and equations used in the verification model. Actual flows were used wherever they existed

Table IV-_ Constant Values and Equations Used in Verification of Model

3.90 Feet/Year crop consumptive use rate for IID

4.15 Feet/year crop consumptive use rate for CVWD

5.900 Feet/year evaporation rate from Sea surface at zero rainfall.

3.0% Sea bank storage factor

IID salt leaching equation is, leached (tons) = 205,172+122,331*rain (in inches)

Salinity of water from Mexico = by Tons/af = -0.09889+0.210374*rain(")+0 004501*NIB (ppm)

400 ppm = salinity of CVWD groundwater going to Sea

2,500 ppm = salinity of CVWD drain water going to Sea

200 ppm = salinity of Coachella Valley flood water going to Sea

73.36 °F average temp. used. Yearly temp. minus this times below rate = effects of temp.

0.11 AF/Acre change in evaporation rate per °F temperature factor

44,316 AF/yr=total IID other system evap made up of 7,386 surface canal acres +AACanal acres=488+main canal acres=1,256+concrete lateral acres=2,015 +earth lateral acres=1,012+reservoir acres=250+drains=2,365, all times 6 AF/Acre

1,350,000 Tons/year = Sulfate combined salt tonnage precipitating out after 1979

900,000 Tons/year = NaCl picked up from IID soils and Sea bottom throughout period

900,000 Tons/year = calcium and HCO_3 precipitated out beginning after 1954

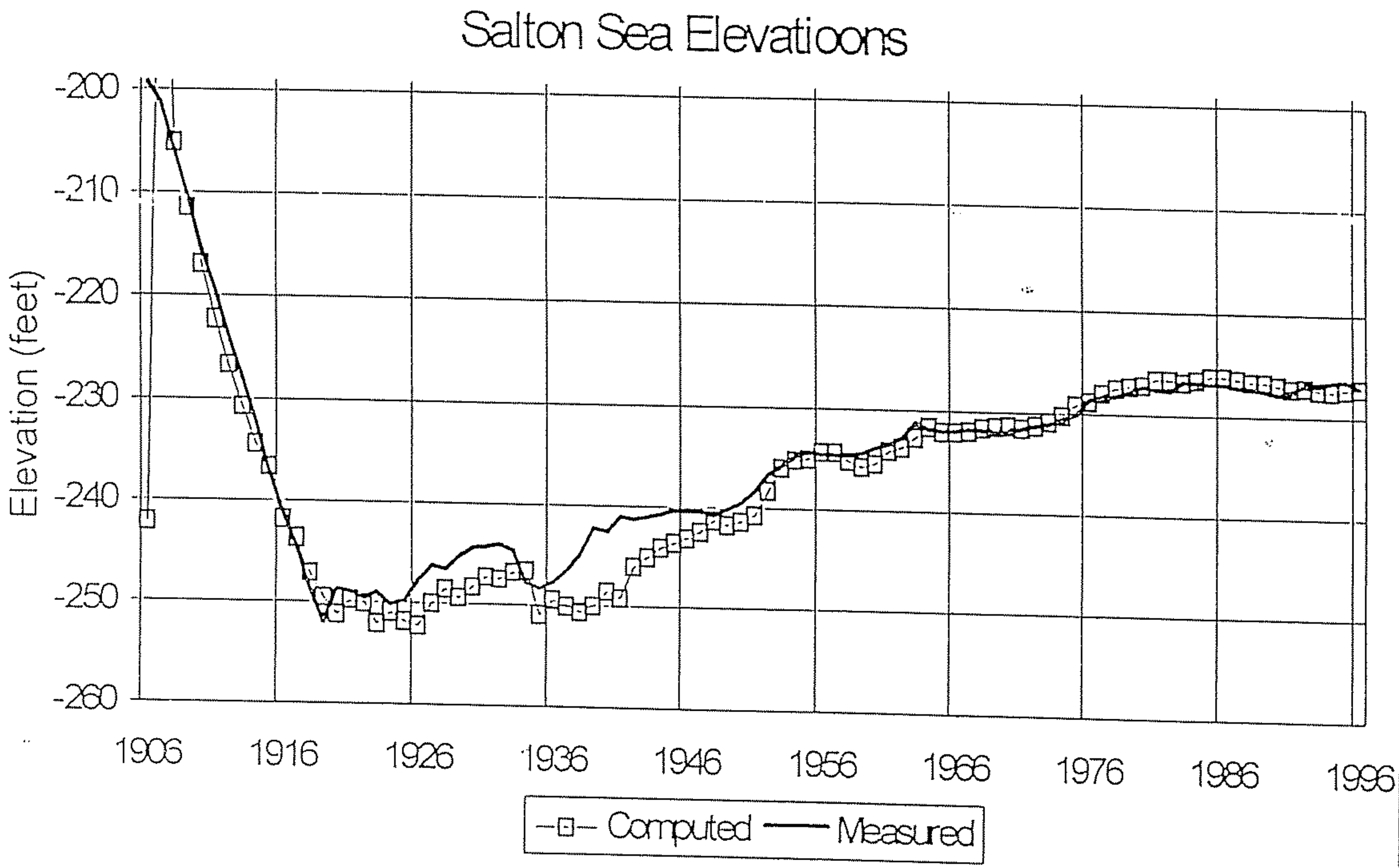
Whitewater River Virgin flow (AF/yr) = 72,000*Beaumont precip. for yr./avg. Beaumont precip.

Whitewater River flood flow is conditional. If virgin flow less than 72,000 acre-feet, no flood water. If virgin flow greater than 72,000 acre-feet, flood flow = (virgin flow - 72,000)^0.9

Groundwater flow from Coachella Valley dependant on reference groundwater elevation and Sea elevation. GW flow (in AF/year = 384*(reference elevation - Salton Sea elevation)

Salton Sea elevation from volume equation Elevation = IF volume>=221800, then elevation = (LN(vol/221800)/0.012242)-235 else, elevation =(LN(vol/221800)/0.023816)-235)

Salton Sea area from elevation ==IF elevation>=-235, then area =0 012242*(volume-5360100)+221800 else area = 0 023816*(volume-5360100)+221800


Salton Sea Elevatioons
Elevation (feet)
-200
-210
-220
-230
-240
-250
-260
1906
1916
1926
1936
1946
1956
1966
1976
1986
1996
Computed
Measured
Figure IV-2

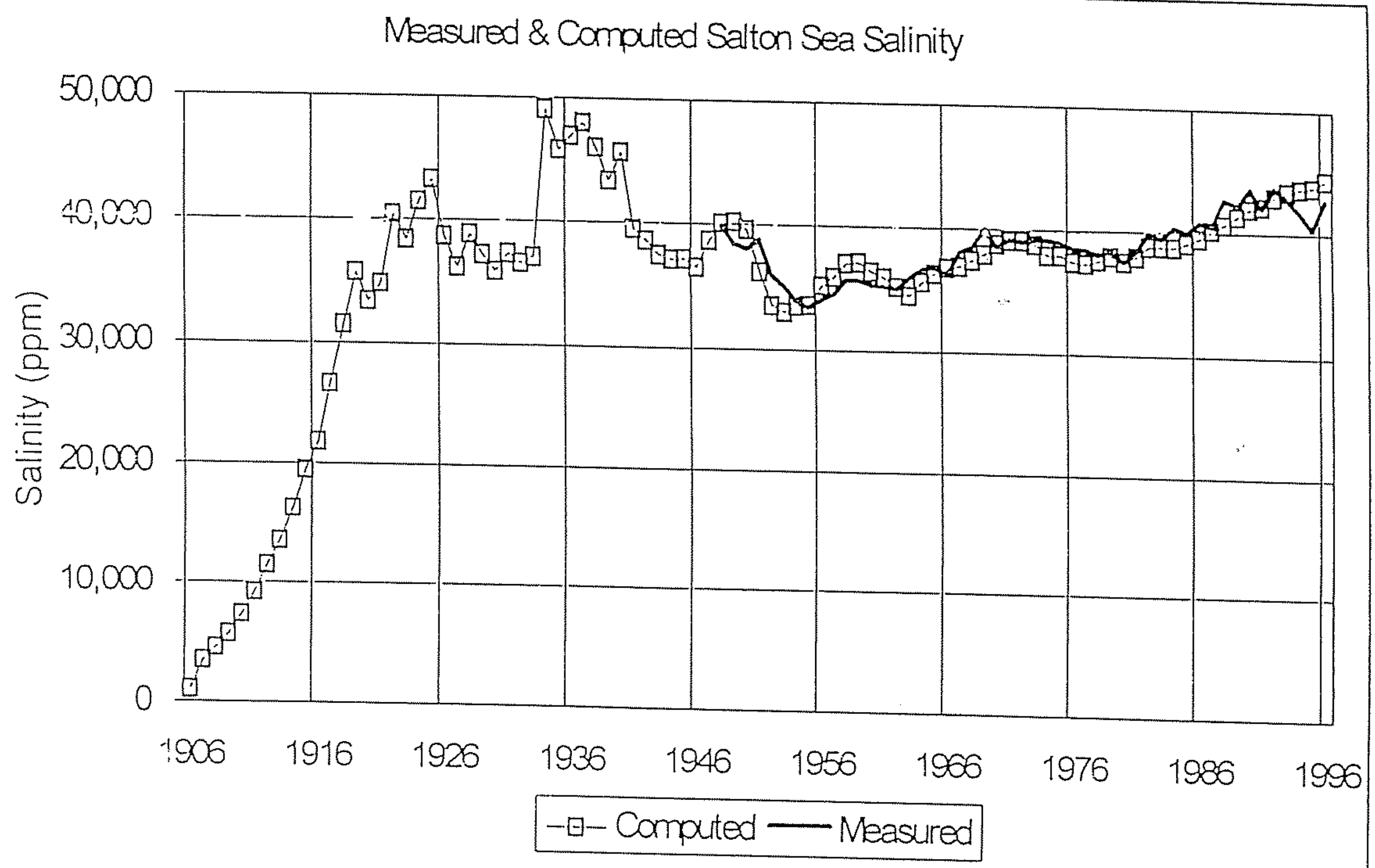

Measured & Computed Salton Sea Salinity
Salinity (ppm)
50,000
40,000
30,000
20,000
10,000
0
1906
1916
1926
1936
1946
1956
1966
1976
1986
1996
Computed
Measured

Figure IV-3

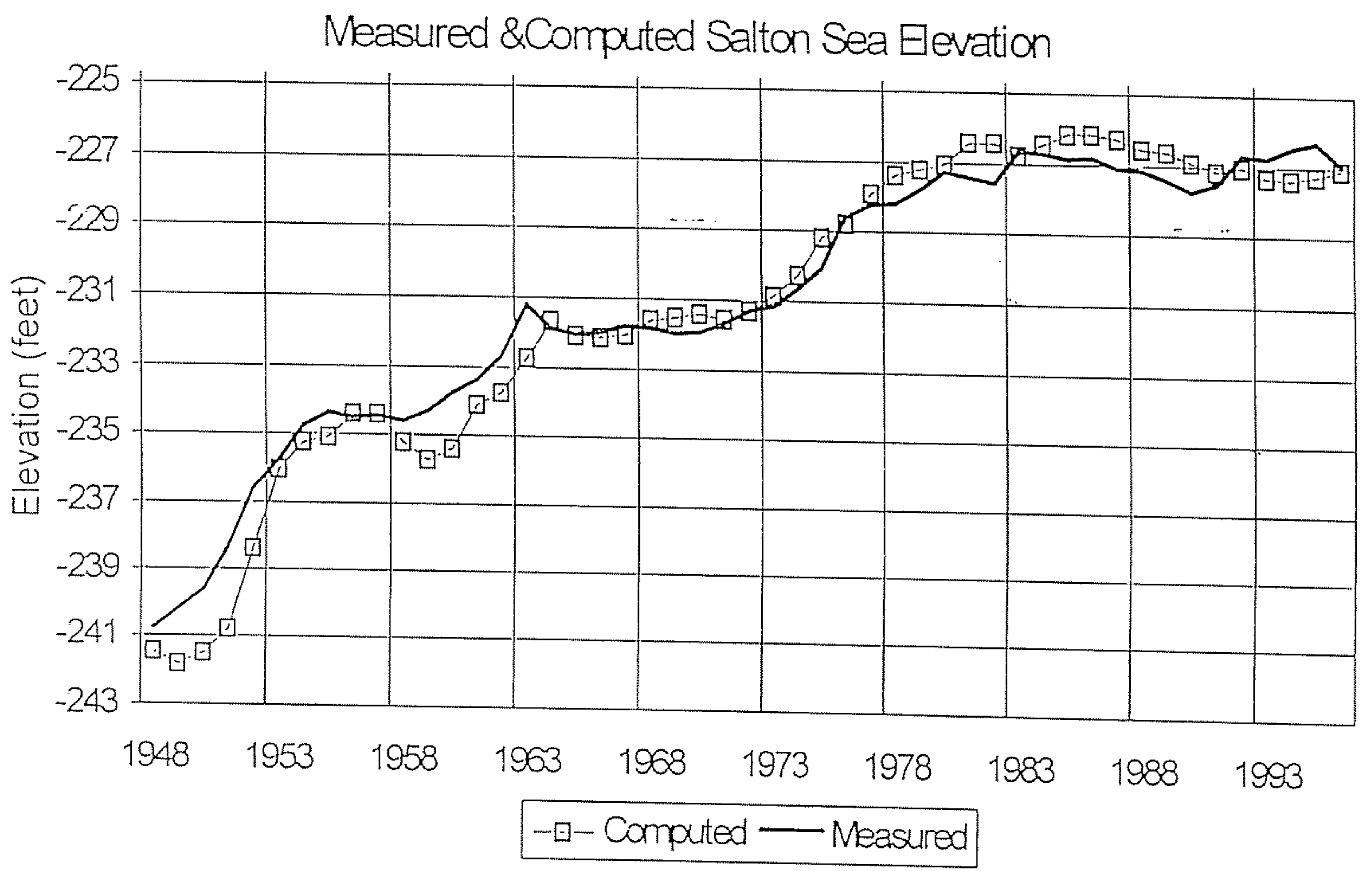

Measured &Computed Salton Sea Elevation
Elevation (feet)
-225
-227
-229
-231
-233
-235
-237
-239
-241
-243
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
Computed
Measured

Figure IV-4

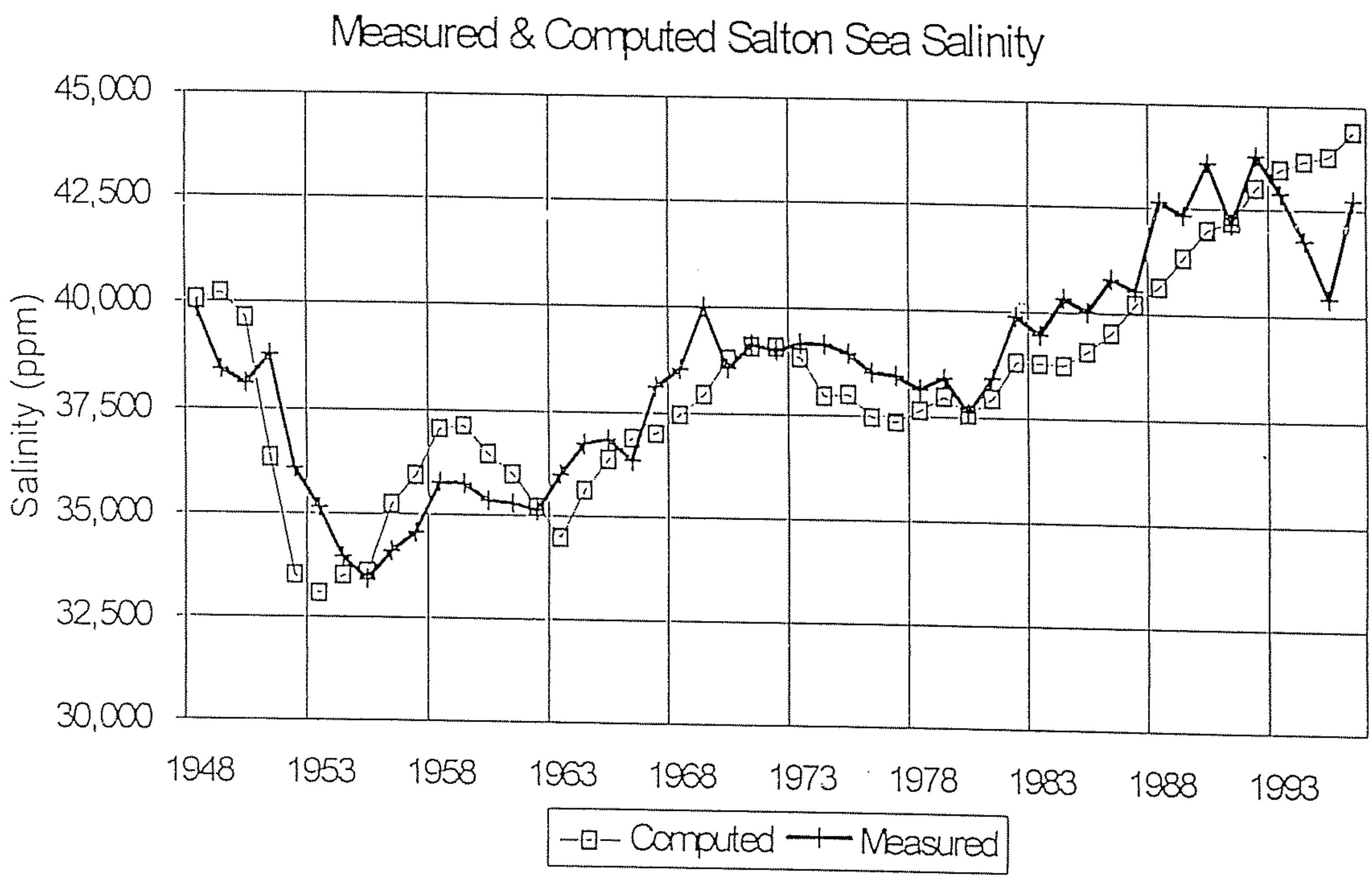

Measured & Computed Salton Sea Salinity
Salinity (ppm)
45,000
42,500
40,000
37,500
35,000
32,500
30,000
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
Computed
Measured

Figure IV-5

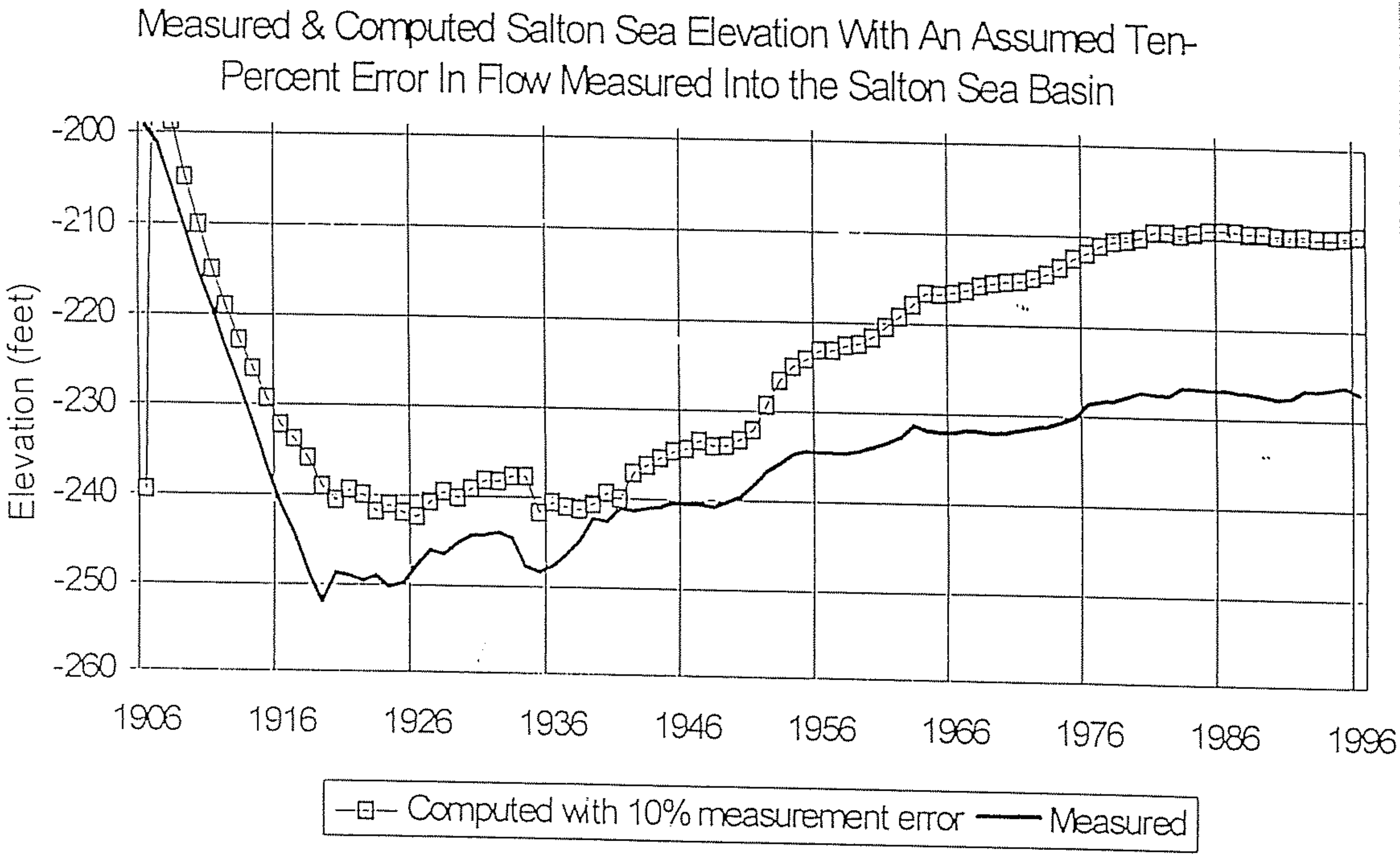


Figure IV-6, showing effect on Sea elevation if flow diverted into Salton Sea basin for its entire period were 10% higher than measured, with all else being equal. This represents a 10% measuring error.

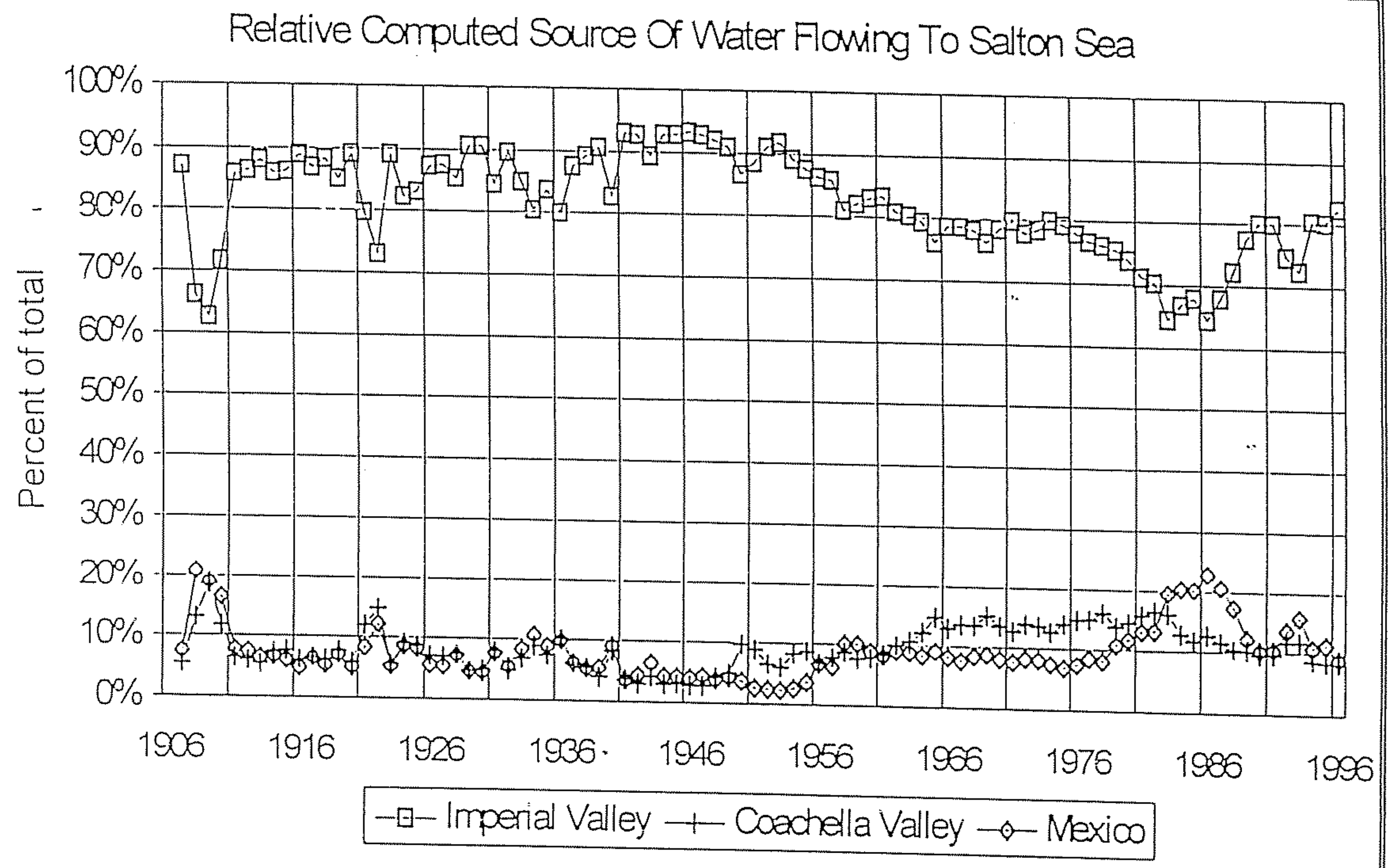
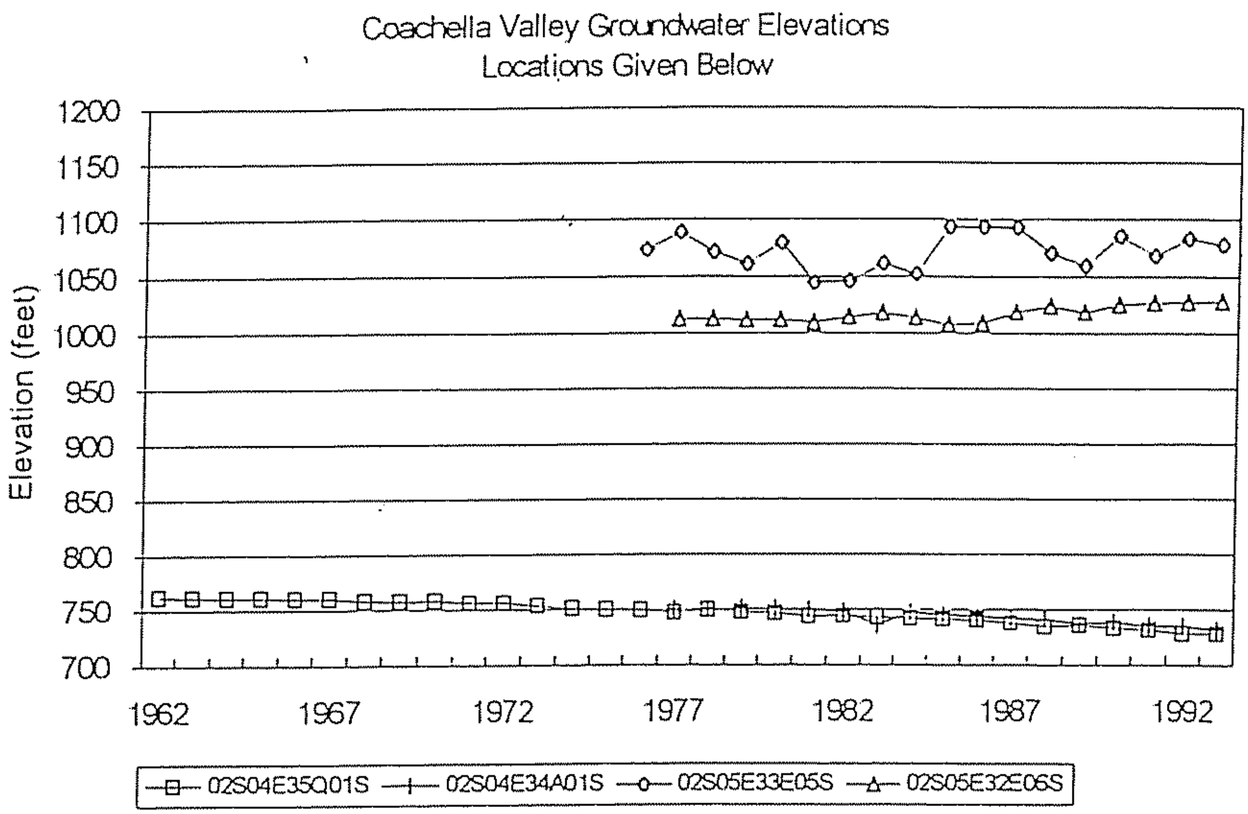
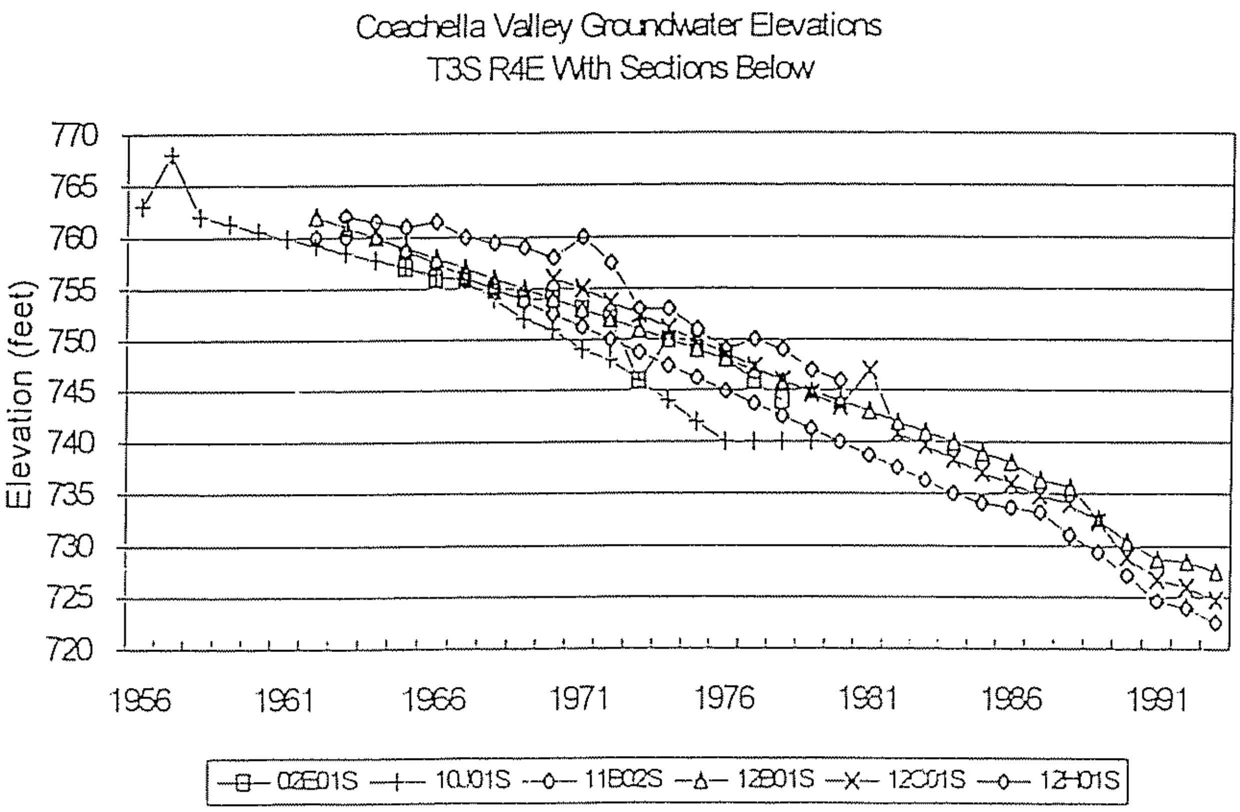
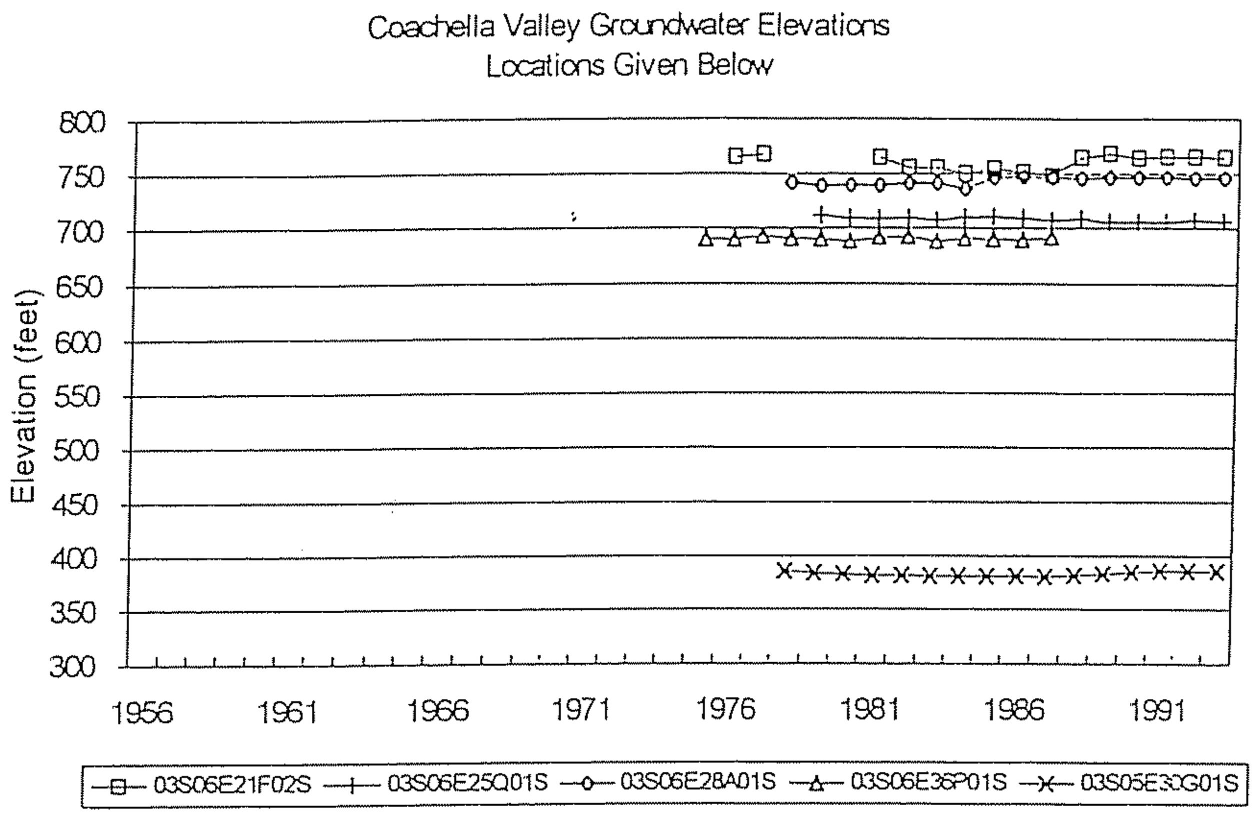
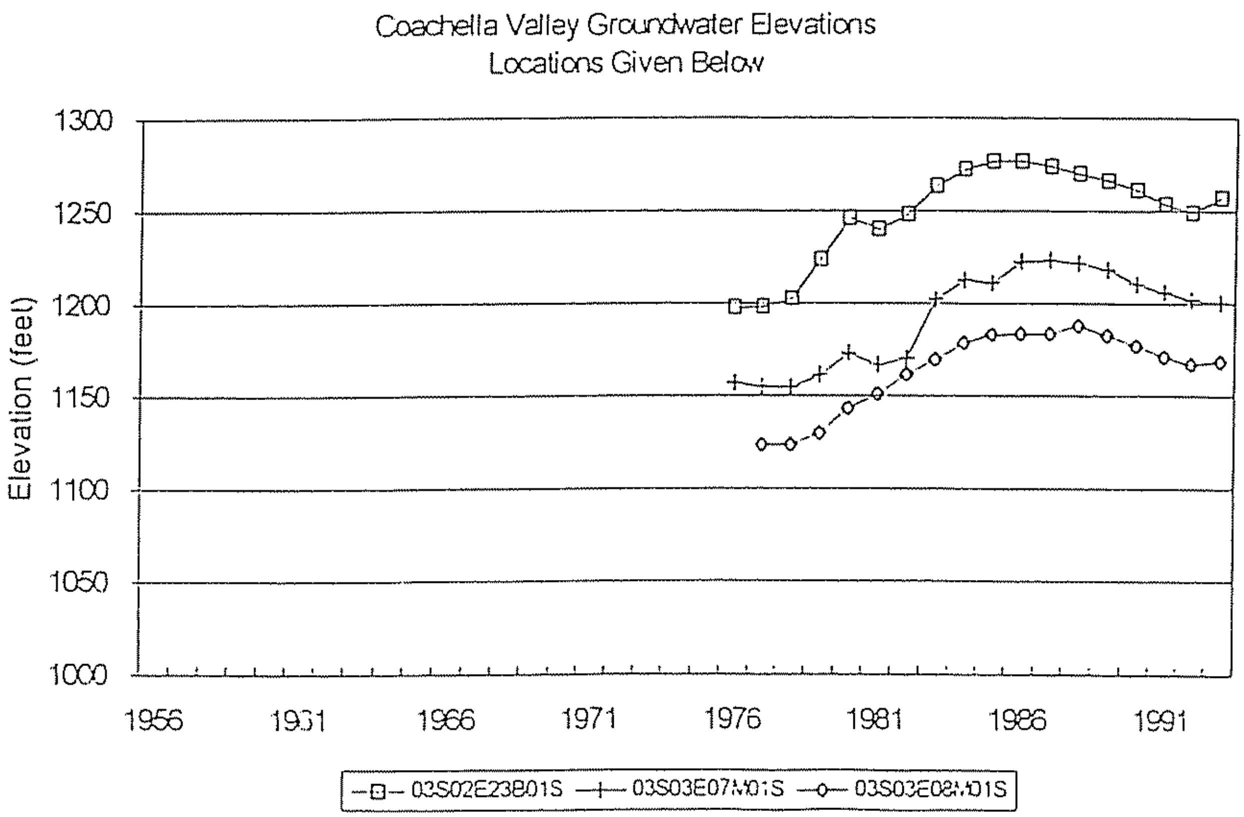

Relative Computed Source Of Water Flowing To Salton Sea
Percent of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1906
1916
1926
1936
1946
1956
1966
1976
1986
1996
Imperial Valley
Coachella Valley
Mexico

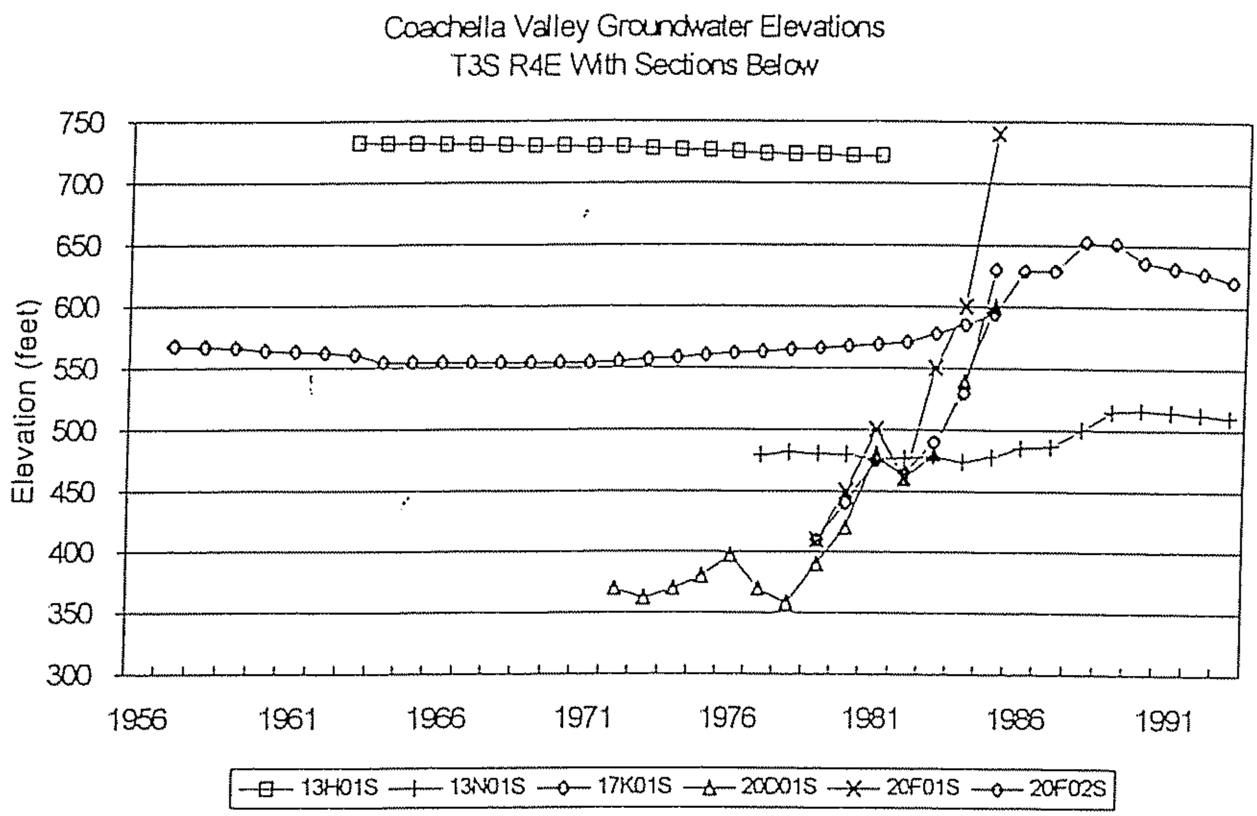
Figure IV-7

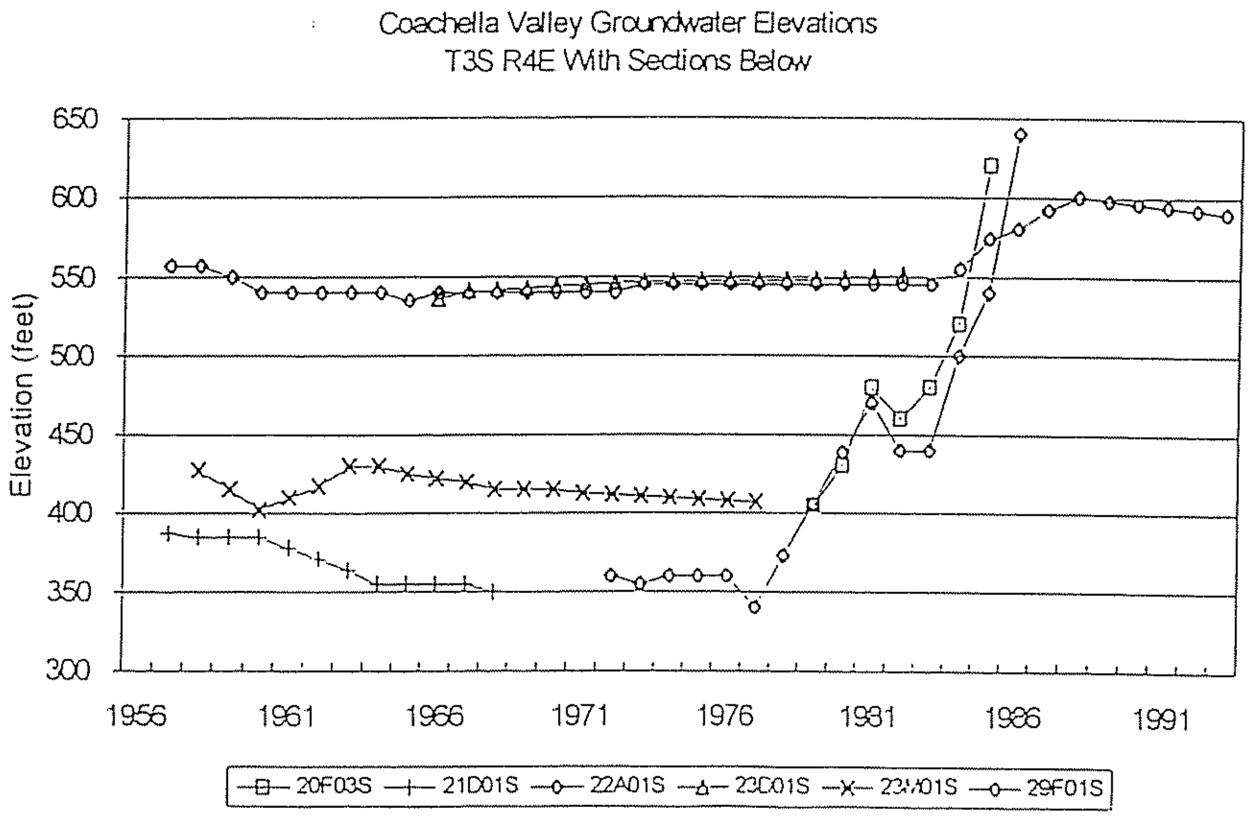

Coachella Valley Groundwater Elevations
Locations Given Below
Elevation (feet)
1200
1150
1100
1050
1000
950
900
850
800
750
700
1962
1967
1972
1977
1982
1987
1992
02S04E35Q01S
02S04E34A01S
02S05E33E05S
02S05E32E06S

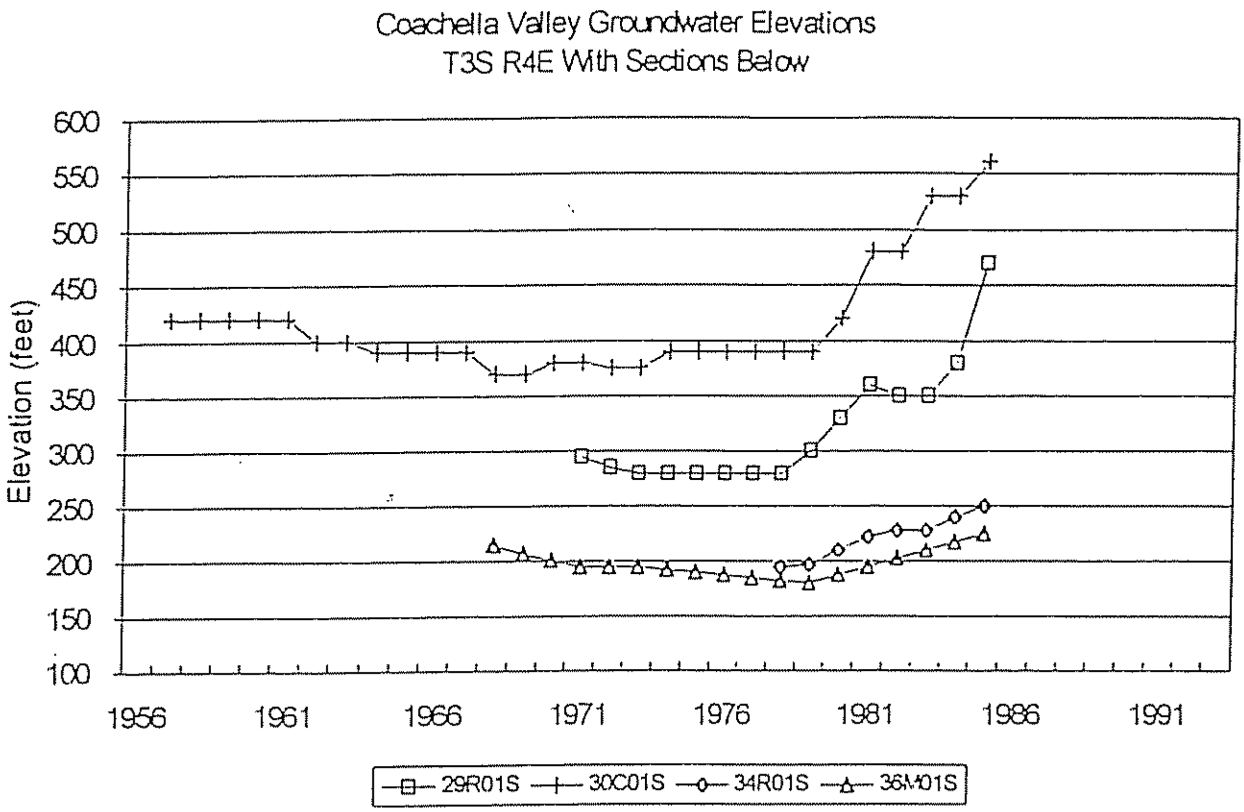

Coachella Valley Groundwater Elevations
T3S R4E With Sections Below
Elevation (feet)
770
765
760
755
750
745
740
735
730
725
720
1956
1961
1966
1971
1976
1981
1986
1991
02E01S
10J01S
11B02S
12B01S
12C01S
12H01S

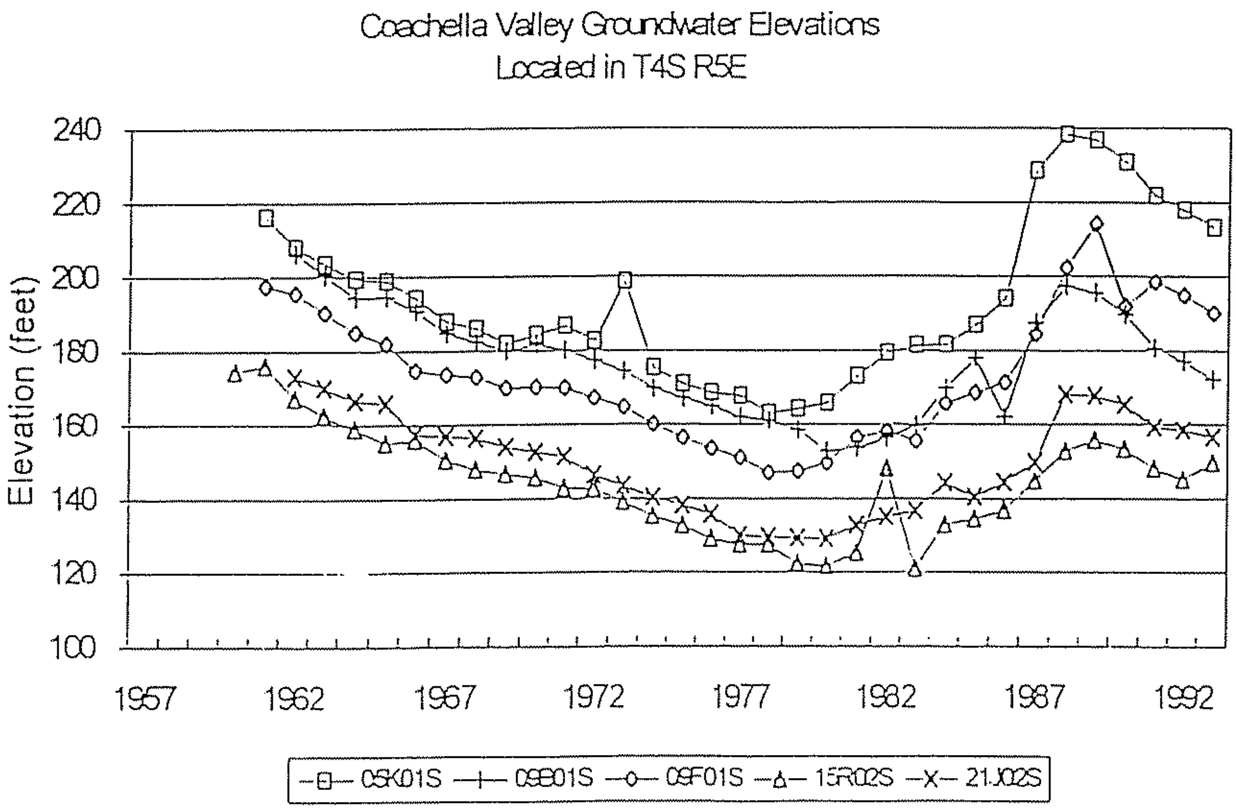

Coachella Valley Groundwater Elevations
Locations Given Below
Elevation (feet)
800
750
700
650
600
550
500
450
400
350
300
1956
1961
1966
1971
1976
1981
1986
1991
03S06E21F02S
03S06E25Q01S
03S06E28A01S
03S06E36P01S
03S05E30G01S

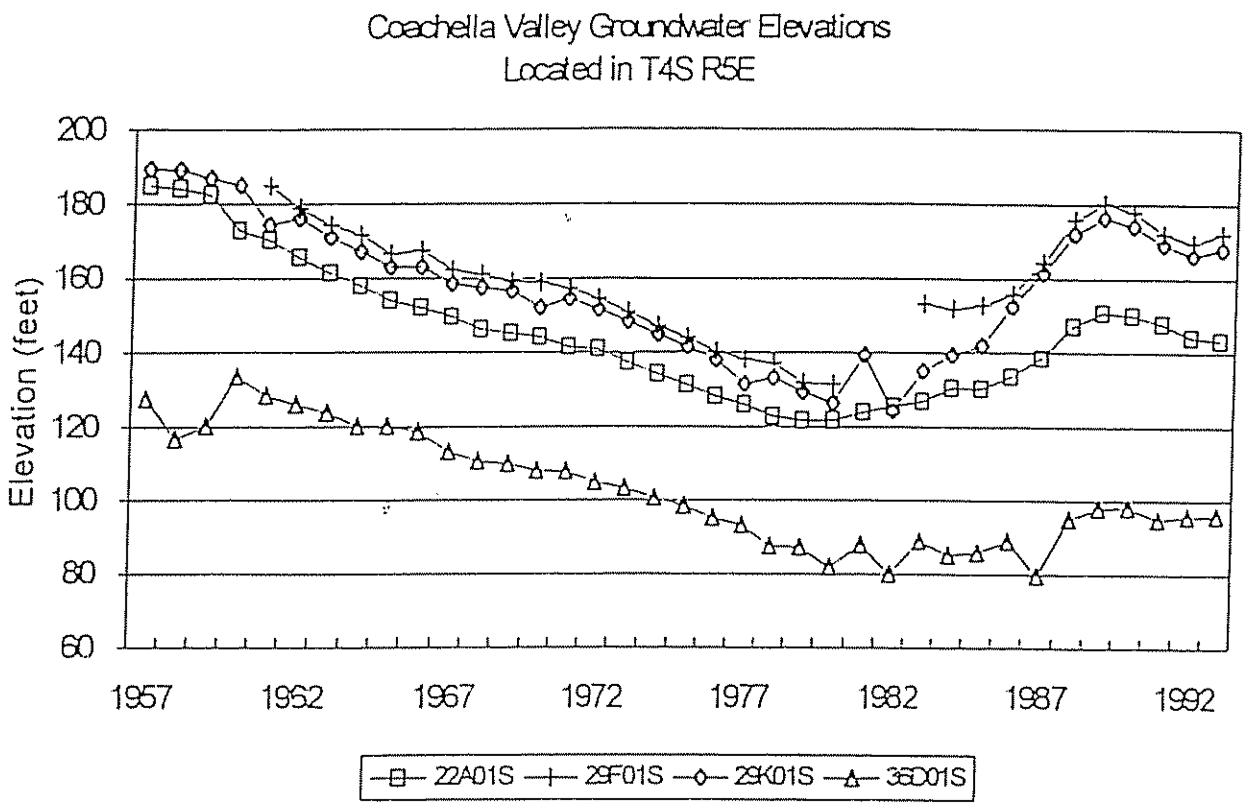

Coachella Valley Groundwater Elevations
Locations Given Below
Elevation (feet)
1300
1250
1200
1150
1100
1050
1000
1956
1961
1966
1971
1976
1981
1986
1991
03S02E23B01S
03S03E07M01S
03S03E08M01S

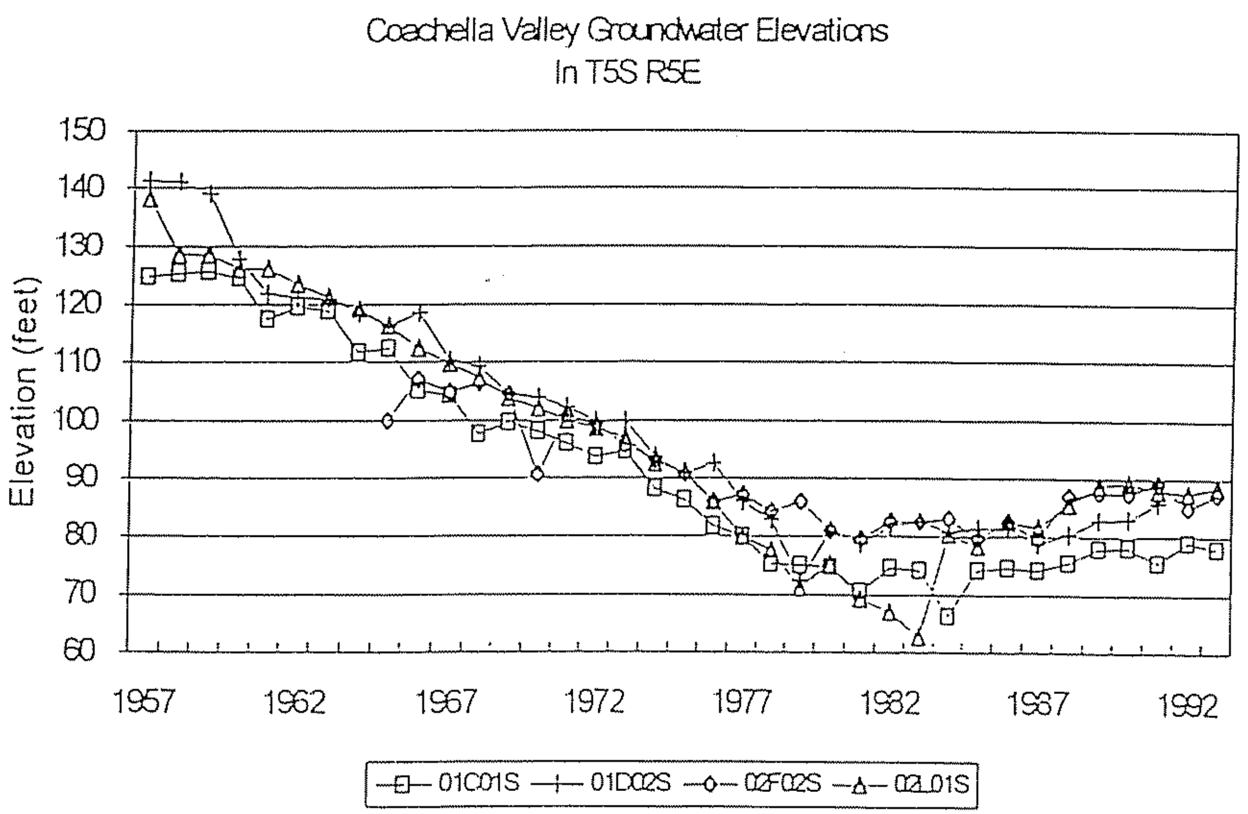

Coachella Valley Groundwater Elevations
T3S R4E With Sections Below
750
700
650
600
550
500
450
400
350
300
Elevation (feet)
1956
1961
1966
1971
1976
1981
1986
1991
13H01S
13N01S
17K01S
20D01S
20F01S
20F02S


Coachella Valley Groundwater Elevations
T3S R4E With Sections Below
650
600
550
500
450
400
350
300
Elevation (feet)
1956
1961
1966
1971
1976
1981
1986
1991
20F03S
21D01S
22A01S
23C01S
23W01S
29F01S

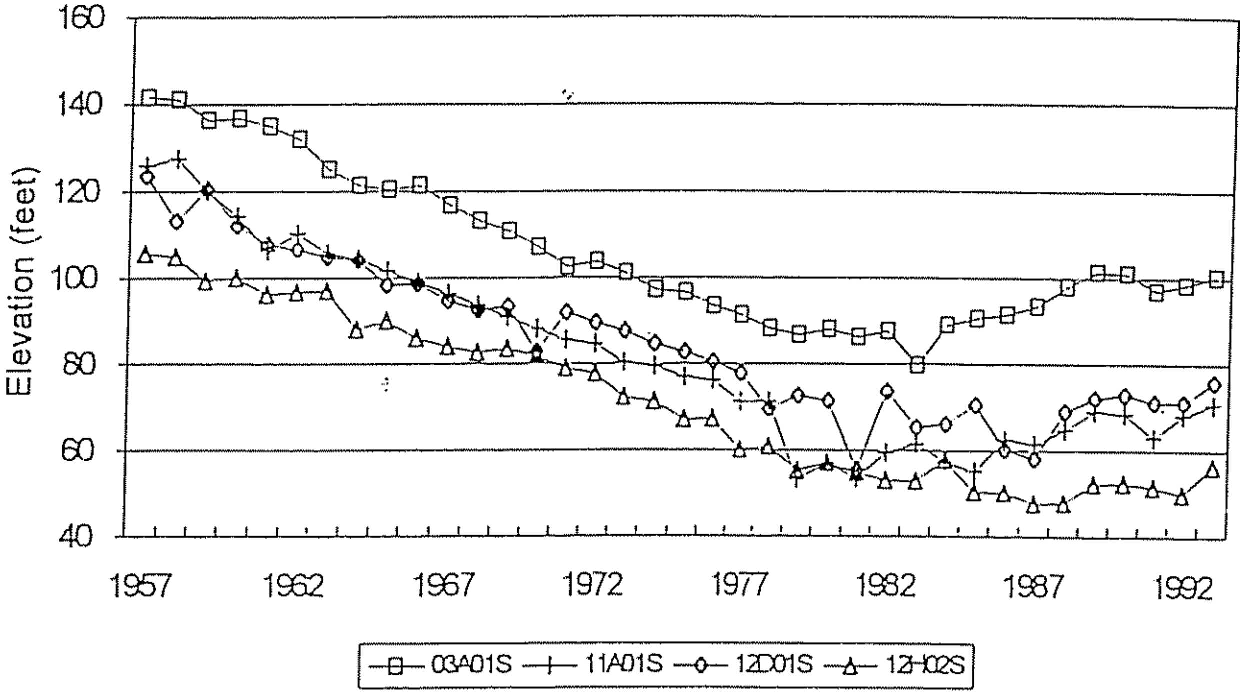

Coachella Valley Groundwater Elevations
T3S R4E With Sections Below
600
550
500
450
400
350
300
250
200
150
100
Elevation (feet)
1956
1961
1966
1971
1976
1981
1986
1991
29R01S
30C01S
34R01S
36M01S


Coachella Valley Groundwater Elevations
Located in T4S R5E
240
220
200
180
160
140
120
100
Elevation (feet)
1957
1962
1967
1972
1977
1982
1987
1992
05K01S
09B01S
09F01S
15R02S
21J02S

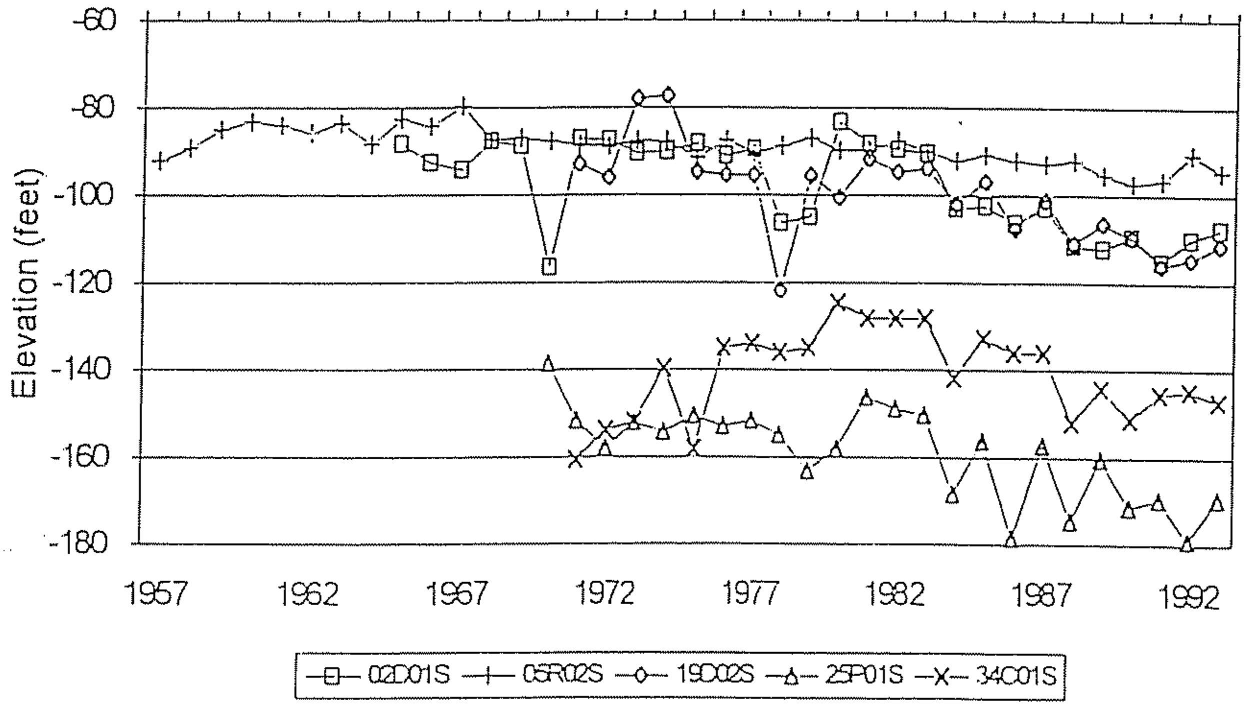

Coachella Valley Groundwater Elevations
Located in T4S R5E
Elevation (feet)
200
180
160
140
120
100
80
60
1957
1962
1967
1972
1977
1982
1987
1992
22A01S
29F01S
29K01S
36D01S


Coachella Valley Groundwater Elevations
In T5S R5E
Elevation (feet)
150
140
130
120
110
100
90
80
70
60
1957
1962
1967
1972
1977
1982
1987
1992
01C01S
01D02S
02F02S
02L01S

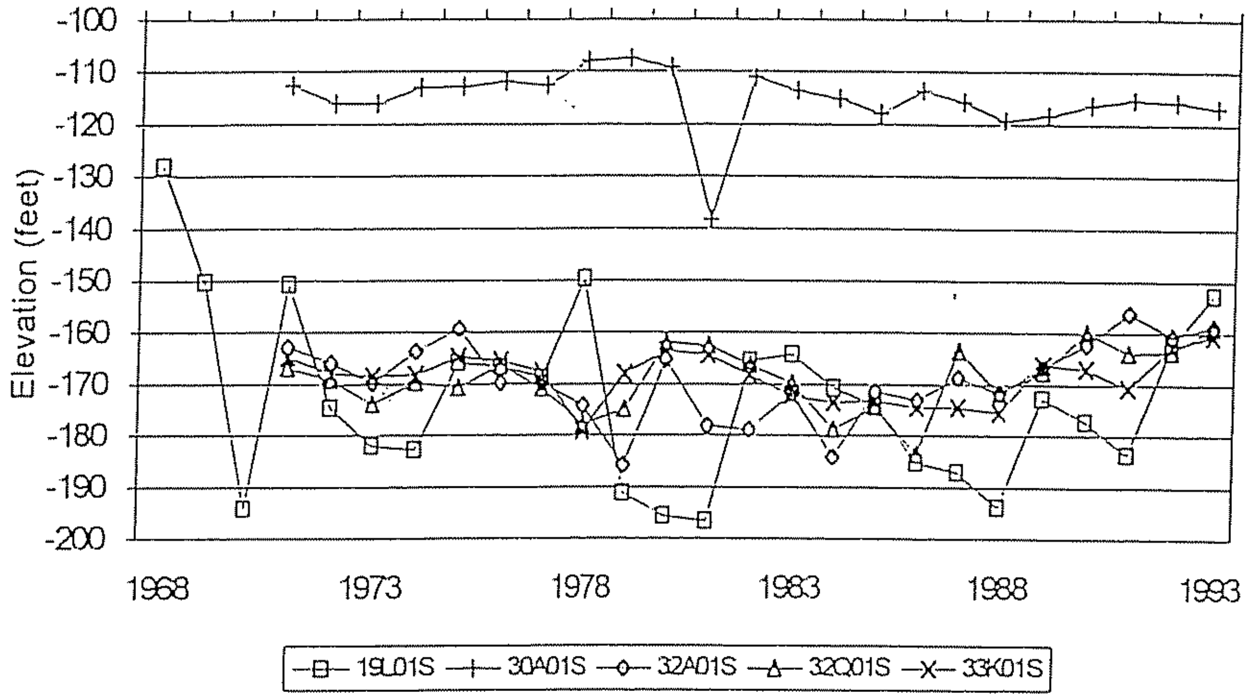
Coachella Valley Groundwater Elevations
In T5S R5E



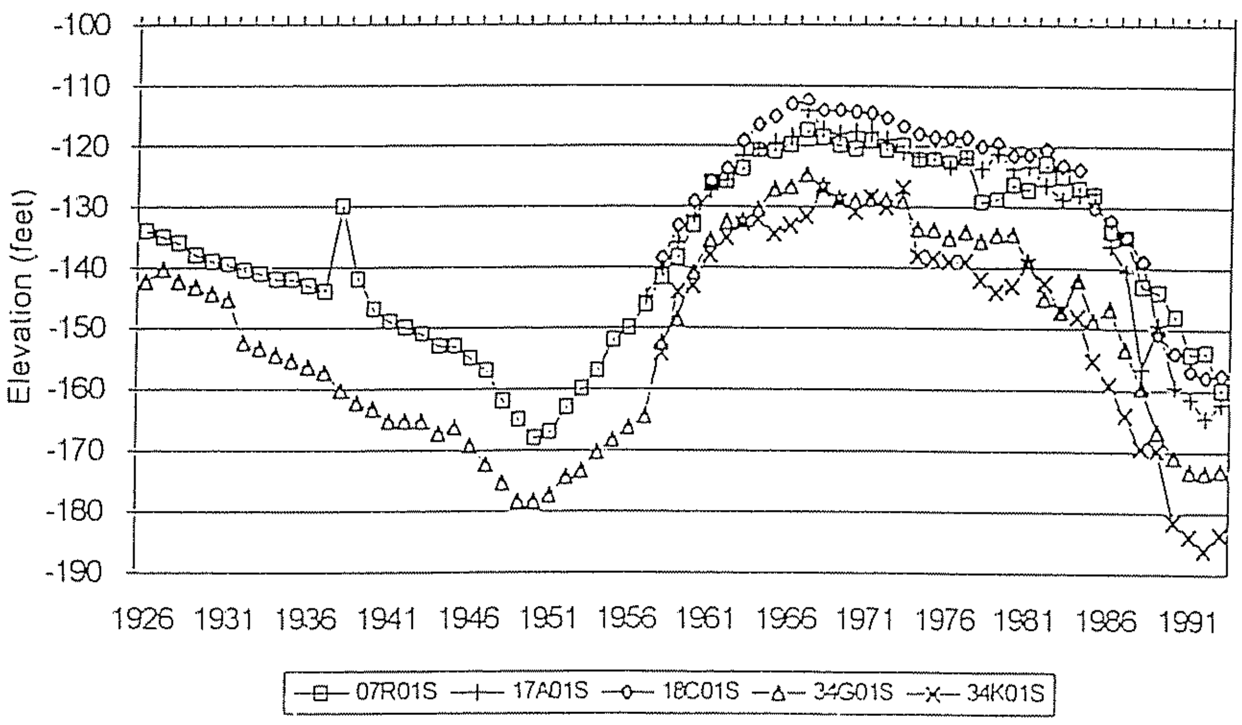
Coachella Valley Groundwater Elevations
In T6S R8E

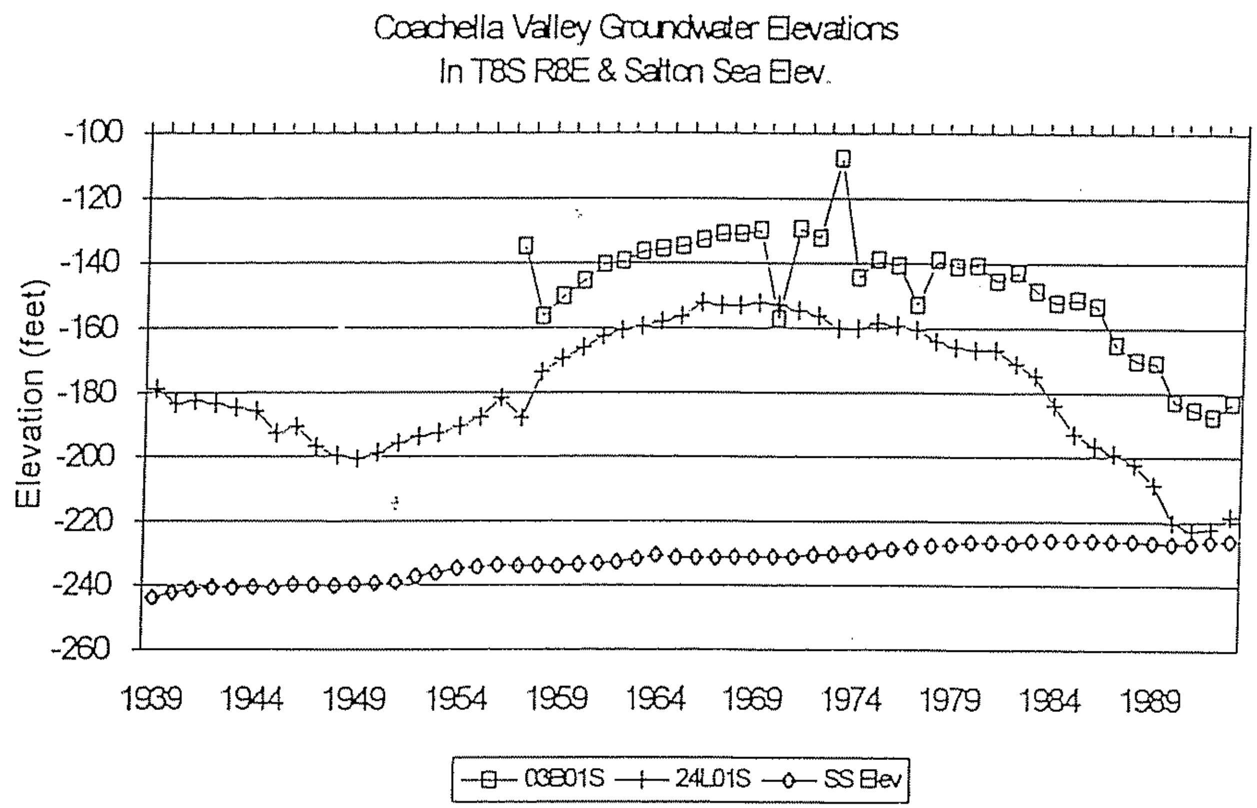


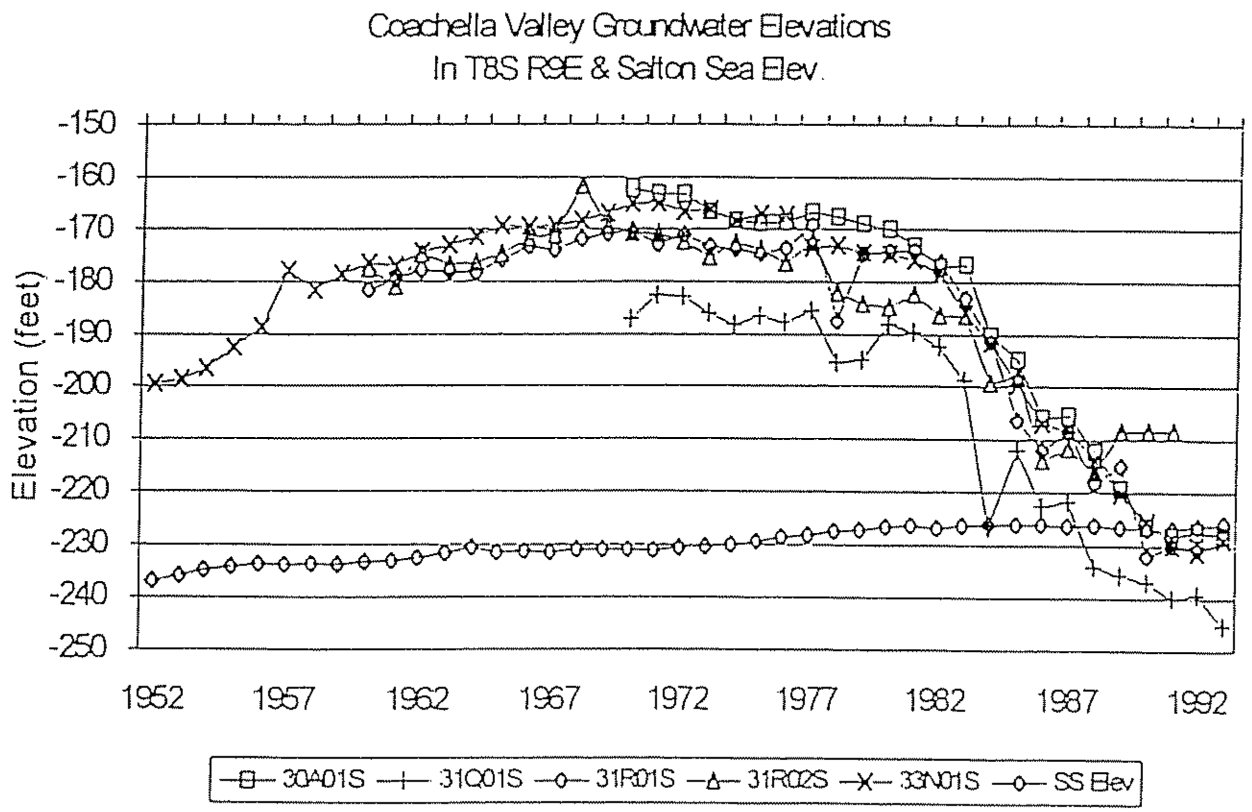
Coachella Valley Groundwater Elevations
In T6S R9E



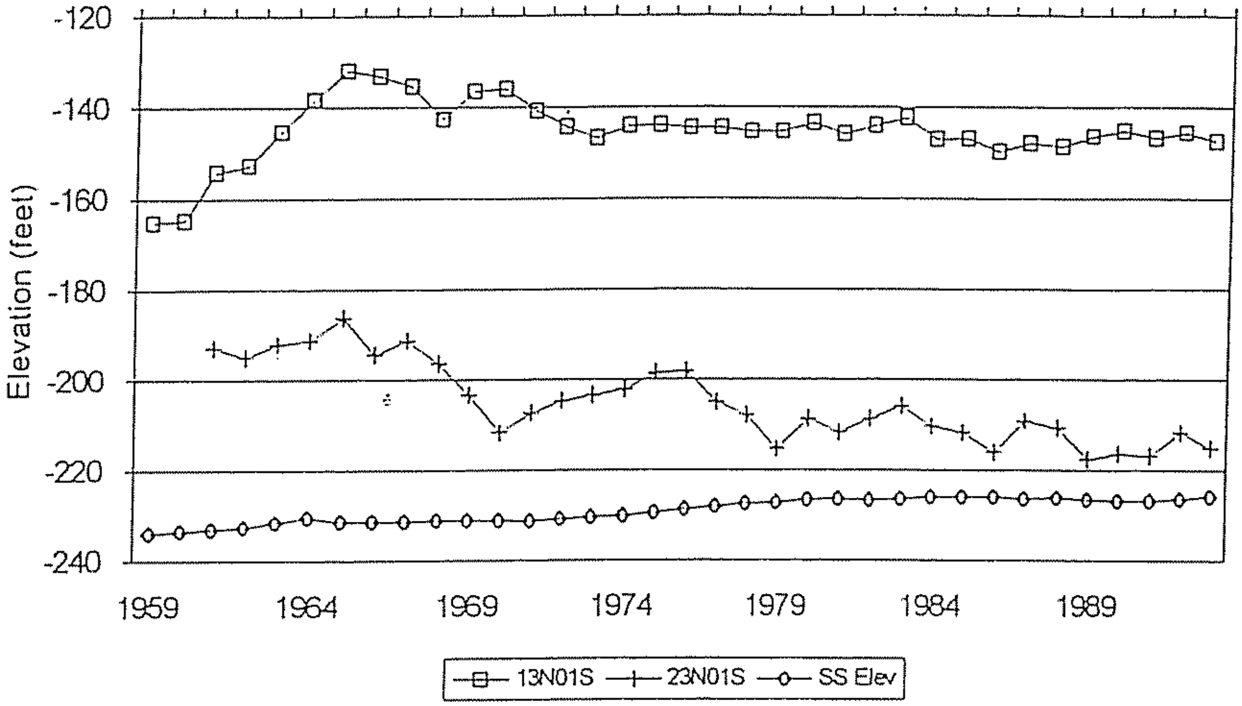
Coachella Valley Groundwater Elevations
In T7S R8E



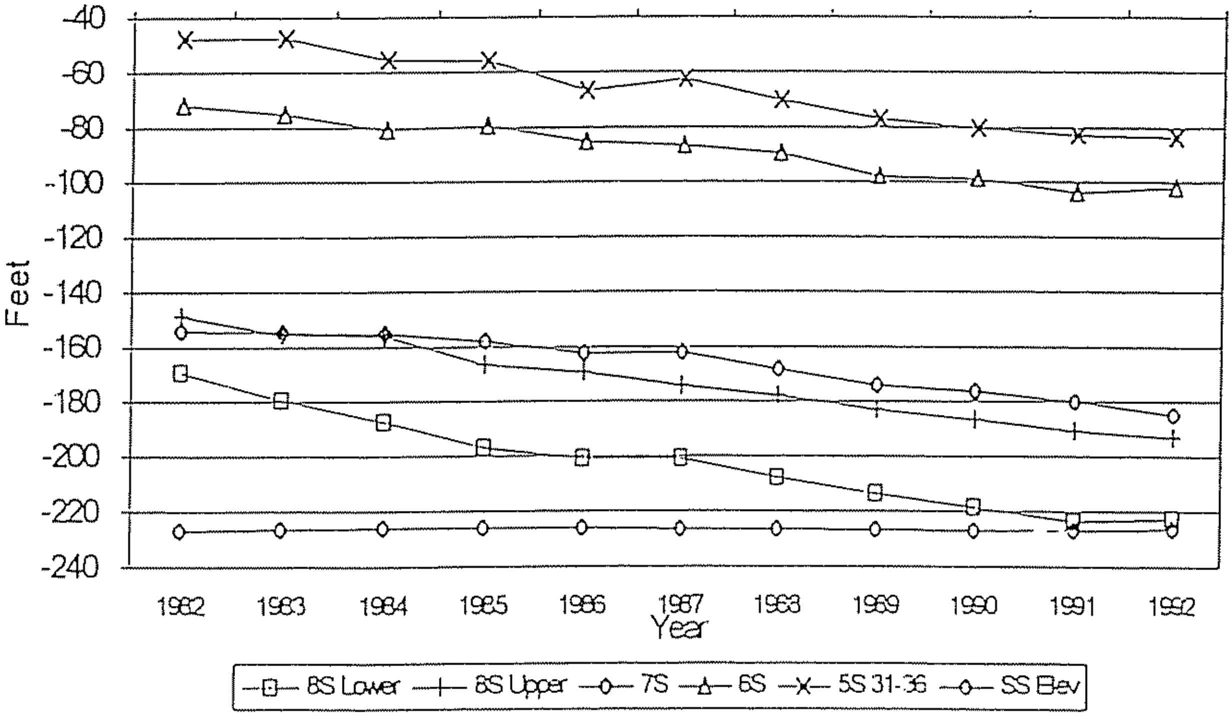

Coachella Valley Groundwater Elevations
In T8S R8E & Salton Sea Elev.
Elevation (feet)
-100
-120
-140
-160
-180
-200
-220
-240
-260
1939
1944
1949
1954
1959
1964
1969
1974
1979
1984
1989
03E01S
24L01S
SS Elev

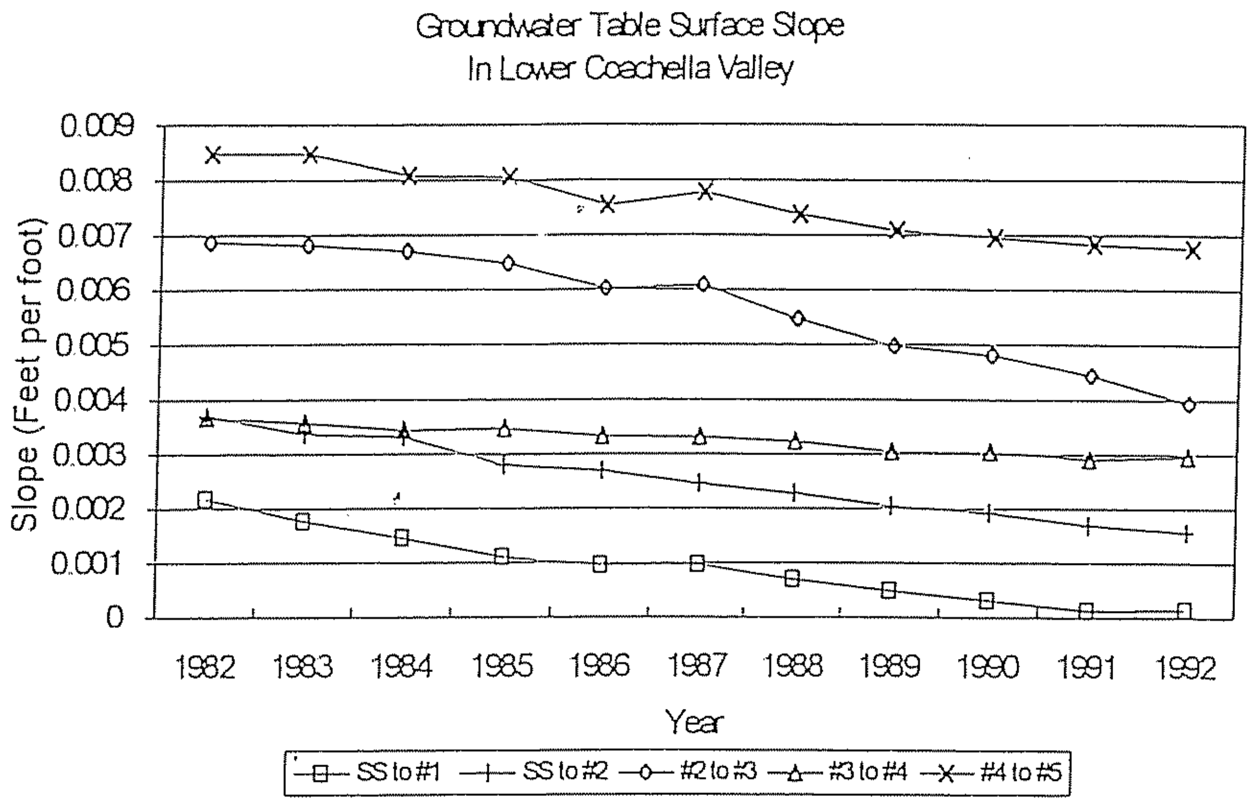

Coachella Valley Groundwater Elevations
In T8S R9E & Salton Sea Elev.
Elevation (feet)
-150
-160
-170
-180
-190
-200
-210
-220
-230
-240
-250
1952
1957
1962
1967
1972
1977
1982
1987
1992
30A01S
31Q01S
31R01S
31R02S
33N01S
SS Elev

Coachella Valley Groundwater Elevations
T9S R7E



103 Wells In Lower Valley
Coachella Valley Groundwater Elevations




Groundwater Table Surface Slope
In Lower Coachella Valley
Slope (Feet per foot)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Year
SS to #1
SS to #2
#2 to #3
#3 to #4
#4 to #5

Appendix B, Table B-1

Year	IID @1117 of AAC or Alamo Canal (AF) (1)	IID Flow to Salton Sea Computed (AF) (2)	IID Flow to Salton Sea Measured (AF) (3)	CVWD at 1117 (AF) (4)	Whitewater River flood Flow (AF) (5)	CVWD CR Drain Flow (AF) (6)	CV Sub-surface To Sea (AF) (7)	Total Coachella Valley to Sea (AF) (8)	Mexico Flow At Boundary (AF) (9)	El Centro Rainfall (") (10)	IID Temp (°F) (11)	Salinity At Imperial Dam ppm (12)
1905	5,120,000	4,646,383		0	3,289	0	42,130	45,419	40000	5.2	71	579
1906	19,483,000	18,473,410		0	4,657	0	22,736	27,392	40000	4.7	71	612
1907	750,000	459,984		0	4,978	0	23,504	28,481	40000	5.8	71	528
1908	674,800	127,441		0	0	0	25,232	25,232	40000	3.2	71	669
1909	755,500	132,267		0	12,141	0	26,999	39,139	40000	3.1	71	519
1910	857,200	173,742		0	0	0	28,919	28,919	40000	3.6	71	626
1911	1,261,800	439,921		0	2,453	0	30,455	32,908	40000	2.4	71	553
1912	1,320,400	457,218		0	0	0	32,068	32,068	40000	3.2	71	635
1913	1,497,900	543,551		0	0	0	33,681	33,681	40000	3.0	71	743
1914	1,623,700	512,779		0	8,951	0	35,332	44,284	40000	2.5	71	583
1915	1,710,200	565,406		0	13,186	0	37,253	50,439	40000	3.32	71.22	664
1916	1,872,600	732,896		0	11,438	0	38,827	50,265	40000	4.80	71.13	570
1917	1,940,200	533,842		0	0	0	40,056	40,056	40000	1.64	71.13	663
1918	2,138,400	659,108		0	5,613	0	41,669	47,282	40000	1.85	70.89	743
1919	2,079,500	475,344		0	0	0	43,013	43,013	40000	2.85	70.88	796
1920	2,194,900	700,243		0	4,197	0	41,746	45,944	40000	4.91	70.16	579
1921	1,826,900	379,654		0	15,391	0	41,861	57,253	40000	6.03	70.76	670
1922	1,832,100	237,253		0	6,215	0	42,092	48,306	40000	2.57	70.59	670
1923	1,981,200	670,199		0	0	0	41,861	41,861	40000	3.51	70.01	612
1924	1,943,300	383,178		0	0	0	42,322	42,322	40000	0.66	72.50	784
1925	1,866,500	405,442		0	0	0	42,130	42,130	40000	2.94	71.49	628
1926	1,929,700	628,819		0	10,914	0	40,759	51,673	40000	6.52	72.64	731
1927	2,146,900	643,946		0	9,821	0	41,066	50,886	40000	4.70	72.26	589
1928	2,215,700	472,687		0	0	0	41,219	41,219	40000	0.28	71.93	733
1929	2,486,400	783,916		0	0	0	40,336	40,336	40000	1.64	70.68	638
1930	2,545,700	816,802		0	5,349	0	39,030	44,380	40000	1.90	70.28	771
1931	2,115,600	442,908		0	4,238	0	37,264	41,502	40000	4.75	72.11	976

Appendix B, Table B-1

	IID @1117 of AAC or Alamo Canal (AF) (1)	IID Flow to Salton Sea Computed (AF) (2)	IID Flow to Salton Sea Measured (AF) (3)	CVWD at 1117 (AF) (4)	Whitewater River flood Flow (AF) (5)	CVWD CR Drain Flow (AF) (6)	CV Sub-surface To Sea (AF) (7)	Total Coachella Valley to Sea (AF) (8)	Mexico Flow At Boundary (AF) (9)	El Centro Rainfall (") (10)	IID Temp (°F) (11)	Salinity At Imperial Dam ppm (12)
1932	2,149,700	657,898		0	1,868	0	34,307	36,174	40000	4.62	71.04	632
1933	1,990,000	408,291		0	0	0	32,617	32,617	40000	2.38	71.23	812
1934	1,336,400	(473,463)		0	0	0	33,462	33,462	40000	0.62	75.39	1401
1935	1,894,000	375,204		0	0	0	33,270	33,270	40000	5.32	72.13	780
1936	2,151,400	325,068		0	8,851	0	32,655	41,506	40000	1.59	73.54	1119
1937	2,359,100	556,828		0	7,565	0	31,388	38,953	40000	1.49	72.25	847
1938	2,310,700	669,887		0	10,816	0	29,967	40,783	40000	3.84	72.10	790
1939	2,105,300	670,876		0	0	0	29,007	29,007	40000	8.52	71.72	788
1940	2,033,000	361,701		0	6,977	0	28,930	35,907	40000	5.07	74.06	791
1941	2,529,500	1,080,136		0	14,566	0	27,154	41,720	40000	6.62	71.65	774
1942	2,457,900	861,988		0	0	0	27,173	27,173	40000	2.49	72.61	748
1943	2,375,500	811,186		0	11,414	0	26,981	38,395	57,723	4.46	72.83	688
1944	2,495,000	876,896		17,616	1,136	0	26,501	27,637	39,970	3.59	71.10	694
1945	2,565,600	847,791		149,960	2,148	0	25,512	27,660	37,697	2.81	71.97	700
1946	2,747,500	982,263		128,006	3,843	0	25,311	29,153	42,052	3.15	72.31	694
1947	2,683,400	785,159		109,163	0	0	24,014	24,014	36,120	0.49	72.48	710
1948	2,777,000	909,669		164,800	0	17,700	22,978	40,678	37,547	1.33	71.40	688
1949	2,812,000	971,880		161,900	0	30,600	21,662	52,262	44,038	2.29	71.62	639
1950	2,988,700	983,601		342,600	0	89,300	21,048	110,348	41,435	0.45	73.33	656
1951	3,116,600	1,304,718		487,900	0	110,800	20,548	131,348	36,807	3.12	71.94	686
1952	3,253,400	1,409,027		495,600	6,019	71,700	22,875	100,595	37,168	2.64	72.38	647
1953	3,386,700	1,329,160		523,300	0	63,700	23,274	86,974	32,424	0.20	72.59	669
1954	3,151,800	1,109,150		572,200	2,265	78,300	24,000	104,564	30,939	0.83	73.81	707
1955	3,046,400	1,172,491		595,500	0	92,400	25,148	117,548	48,900	2.53	71.98	807
1956	2,998,300	999,117		565,200	0	52,600	26,795	79,395	78,174	0.16	72.61	891
1957	2,864,400	994,835		512,700	3,401	58,900	27,770	90,071	72,607	3.35	72.94	847
1958	2,785,900	842,638	974,045	501,800	6,137	54,600	30,502	91,239	105,974	2.71	74.33	726
1959	2,898,200	998,917	1,200,963	502,900	0	62,200	31,832	94,032	123,643	1.97	73.96	729

	IID @1117 of AAC or Alamo Canal (AF) (1)	IID Flow to Salton Sea Computed (AF) (2)	IID Flow to Salton Sea Measured (AF) (3)	CVWD at 1117 (AF) (4)	Whitewater River flood Flow (AF) (5)	CVWD CR Drain Flow (AF) (6)	CV Sub-surface To Sea (AF) (7)	Total Coachella Valley to Sea (AF) (8)	Mexico Flow At Boundary (AF) (9)	El Centro Rainfall (") (10)	IID Temp (°F) (11)	Salinity At Imperial Dam ppm (12)
1960	3,059,750	1,143,403	1,060,037	505,830	0	75,900	33,335	109,235	123,000	1.74	73.60	768
1961	3,035,530	1,187,899	1,050,526	522,120	0	85,070	34,315	119,385	117,000	1.87	72.78	802
1962	3,006,130	1,189,086	1,088,849	564,740	0	112,690	35,035	147,725	134,000	1.85	73.23	820
1963	3,062,490	1,264,645	1,153,891	537,640	0	133,330	35,035	168,365	141,000	2.43	72.99	800
1964	2,807,670	1,013,622	906,074	511,080	0	121,000	36,072	157,072	106,000	0.93	71.78	821
1965	2,688,150	938,072	883,099	514,760	7,220	138,788	36,897	182,906	113,000	3.21	72.48	888
1966	2,886,370	999,915	1,004,188	480,040	0	128,073	37,387	165,460	105,000	1.61	73.57	886
1967	2,769,590	998,626	1,027,970	455,950	2,045	133,783	37,454	173,282	98,000	4.25	72.94	841
1968	2,864,170	988,727	1,001,027	473,490	0	133,097	37,483	170,580	107,000	1.99	73.48	838
1969	2,714,480	914,416	962,639	486,000	14,222	130,583	37,445	182,250	105,000	3.50	73.89	877
1970	2,807,800	973,238	1,020,503	442,900	0	131,253	36,773	168,026	101,000	1.68	73.03	896
1971	2,938,790	1,139,041	1,092,571	466,170	0	142,977	37,464	180,441	109,000	1.29	71.59	892
1972	2,903,490	1,065,046	1,063,537	501,040	0	155,126	36,907	192,033	113,000	2.16	72.99	861
1973	3,008,680	1,148,240	1,065,414	511,690	0	163,211	36,571	199,782	119,000	1.28	72.73	843
1974	3,133,060	1,218,534	1,123,492	551,540	0	157,208	35,457	192,665	113,000	1.98	73.56	835
1975	3,046,910	1,179,747	1,128,268	566,300	0	173,602	35,505	209,107	101,000	1.19	71.98	829
1976	2,831,440	1,103,176	1,084,993	516,160	0	174,684	34,737	209,421	104,000	5.08	72.88	821
1977	2,717,190	976,738	1,020,844	498,550	0	156,787	33,988	190,775	109,000	5.21	74.03	818
1978	2,715,000	945,913	995,674	501,370	21,660	144,098	33,518	199,276	100,000	4.37	74.19	812
1979	2,843,730	1,007,283	1,056,672	523,370	0	151,002	33,115	184,117	146,000	2.35	73.52	801
1980	2,817,120	991,112	1,043,241	526,260	17,226	143,958	32,827	194,010	158,000	4.35	74.51	760
1981	2,839,490	857,928	962,925	447,200	0	156,788	33,009	189,797	158,000	2.52	75.32	821
1982	2,565,490	841,131	888,575	419,540	12,851	152,282	31,943	197,076	159,000	4.84	72.49	826
1983	2,509,280	807,130	867,835	355,340	19,119	150,956	30,253	200,328	245,000	5.72	73.92	727
1984	2,687,120	880,147	895,034	358,530	0	140,985	28,612	169,597	268,000	3.43	74.08	675
1985	2,678,390	870,672	830,841	336,060	0	123,855	26,816	150,671	260,000	3.74	73.10	615
1986	2,692,780	748,212	834,335	341,630	0	122,969	24,281	147,250	265,000	3.73	74.85	577
1987	2,758,680	827,643	851,694	331,870	0	117,032	23,504	140,536	251,000	2.58	73.83	612

	IID @1117 of AAC or Alamo Canal (AF) (1)	IID Flow to Salton Sea Computed (AF) (2)	IID Flow to Salton Sea Measured (AF) (3)	CVWD at 1117 (AF) (4)	Whitewater River flood Flow (AF) (5)	CVWD CR Drain Flow (AF) (6)	CV Sub-surface To Sea (AF) (7)	Total Coachella Valley to Sea (AF) (8)	Mexico Flow At Boundary (AF) (9)	El Centro Rainfall (") (10)	IID Temp (°F) (11)	Salinity At Imperial Dam ppm (12)
1988	2,943,880	951,503	918,726	331,230	0	117,188	21,324	138,512	227,000	1.32	73.76	648
1989	3,004,900	980,293	965,879	358,880	0	110,816	20,259	131,075	155,000	0.75	74.09	683
1990	3,050,020	1,053,415	1,004,383	368,900	0	109,613	17,259	126,872	135,000	1.46	72.93	702
1991	2,894,100	1,018,751	960,365	317,020	5,270	103,866	14,961	124,097	133,000	4.96	72.74	749
1992	2,567,630	793,387	878,485	308,740	9,858	100,817	14,517	125,192	145,000	7.34	73.22	767
1993	2,766,980	885,643	973,811	317,900	25,374	105,126	15,297	145,796	192,000	5.15	73.13	784
1994	3,043,040	1,091,647	1,045,936	325,550	0	103,234	15,185	118,419	147,000	2.45	72.97	797
1995	3,065,490	1,056,809	1,083,992	325,910	0	96,419	15,116	111,535	149,995	2.26	74.00	787
1996	3,154,980	1,088,172	1,076,554	330,750	0	95,668	15,354	111,022	119,755	0.17	73.90	782

Column(1) from IID records except for first two years which are from USGS, and represent total flow from the Colorado River into the SS Basin

Column (2) is computed flow into the Salton Sea from IID.

Column (3) is available measured flow into the SS from IID.

Column (4) is diversion by CVWD at Station 1117 of All-American Canal, from IID records

Column (5) is calculated flood flow (non-agricultural return flow) of Whitewater River. Actual data available 1964 onward, with zero flow in many years.

Column (6) is measured return flow from CVWD, from CVWD.

Column (7) is subsurface flow to SS from Coachella Valley. No records exist. Estimates have been made previously by DWR.

Column (8) is total to SS from Coachella Valley (Columns 5+6+7)

Column (9) is drainage and waste flow crossing International Boundary from Mexico. Records from IID for years 1943 onward. No redords prior to 1943.

Column (10) is rainfall at El Centro, from IID. No records prior to 1915.

Column (11) is temperature at IID yard, from IID. No records prior to 1915.

Column (12) is dissolved solids concentration at Imperial Dam, from USBR 1941 onward. Prior data estimated by Tostrud.

Appendix B, Table B-2

Actual and Measured Salton Sea Elevation, Surface Content, Salinity, and Surface Salt Content

	Elevation (feet)		Sea Content (AF)		Salinity (ppm)		Tons of Salt In Sea		Measured Yearly Salt gain (tons)	Calculated Yearly Salt gain (tons)
	Measured	Calculated	Measured	Calculated	Measured	Calculated	Measured	Calculated		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1905	-249.70	-249.73	2,609,216	3,905,221						
1906	-199.20	-242.13	15,325,218	16,179,101		1,073		23,613,600		
1907	-201.20	-172.03	14,645,982	13,354,348		3,422		62,148,003		38,534,403
1908	-205.70	-205.14	13,177,161	11,403,290		4,471		69,341,119		7,193,116
1909	-210.30	-211.49	11,757,038	9,828,450		5,718		76,426,132		7,085,012
1910	-215.30	-216.99	10,301,484	8,420,993		7,316		83,784,866		7,358,734
1911	-219.30	-222.25	9,199,515	7,315,506		9,165		91,182,024		7,397,158
1912	-223.50	-226.63	8,099,078	6,332,021		11,482		98,879,879		7,697,855
1913	-227.70	-230.73	7,053,793	5,492,653		13,520		100,997,842		2,117,963
1914	-232.00	-234.40	6,037,870	4,656,478		16,236		102,822,462		1,824,619
1915	-237.00	-236.66	4,926,899	3,970,142		19,458		105,062,638		2,240,176
1916	-241.10	-241.79	4,100,808	3,633,921		21,738		107,433,330		2,370,692
1917	-244.30	-243.61	3,509,825	3,029,517		26,624		109,694,218		2,260,888
1918	-248.50	-247.09	2,799,463	2,625,848		31,483		112,428,836		2,734,618
1919	-252.00	-249.59	2,259,428	2,372,394		35,776		115,429,243		3,000,407
1920	-248.70	-251.24	2,767,377	2,600,932		33,416		118,202,265		2,773,022
1921	-249.00	-249.75	2,719,532	2,554,861		34,858		121,119,023		2,916,758
1922	-249.60	-250.05	2,624,863	2,248,083		40,421		123,583,121		2,464,098
1923	-249.00	-252.08	2,719,532	2,417,589		38,375		126,174,098		2,590,977
1924	-250.20	-250.94	2,531,537	2,284,570		41,466		128,836,291		2,662,192
1925	-249.70	-251.83	2,609,216	2,228,273		43,346		131,356,653		2,520,362
1926	-247.80	-252.21	2,912,978	2,560,136		38,699		134,741,666		3,385,013
1927	-246.10	-250.02	3,196,665	2,790,127		36,284		137,683,590		2,941,924
1928	-246.50	-248.56	3,128,878	2,656,923		38,892		140,532,061		2,848,471
1929	-245.20	-249.40	3,351,567	2,832,189		37,264		143,534,275		3,002,214
1930	-244.30	-248.30	3,509,825	3,002,111		36,034		147,122,605		3,588,331
1931	-244.20	-247.26	3,527,620	2,972,296		37,431		151,308,065		4,185,459
1932	-244.00	-247.44	3,563,337	3,097,968		36,673		154,510,859		3,202,795

Appendix B, Table B-2

Actual and Measured Salton Sea Elevation, Surface Content, Salinity, and Surface Salt Content

	Elevation (feet)		Sea Content (AF)		Salinity (ppm)		Tons of Salt In Sea		Measured Yearly Salt gain (tons)	Calculated Yearly Salt gain (tons)
	Measured	Calculated	Measured	Calculated	Measured	Calculated	Measured	Calculated		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1933	-244.60	-246.68	3,456,695	3,126,099		37,116		157,799,161		3,288,302
1934	-247.80	-246.52	2,912,978	2,414,718		49,120		161,311,865		3,512,704
1935	-248.30	-250.96	2,831,703	2,643,722		45,858		164,882,132		3,570,268
1936	-247.70	-249.48	2,929,349	2,648,460		46,988		169,246,631		4,364,499
1937	-246.40	-249.45	3,145,764	2,647,280		48,062		173,037,228		3,790,597
1938	-244.70	-249.46	3,439,069	2,823,556		46,080		176,948,401		3,911,173
1939	-242.20	-248.35	3,892,558	3,071,406		43,409		181,322,743		4,374,341
1940	-242.50	-246.84	3,836,703	2,977,004		45,737		185,177,153		3,854,410
1941	-241.00	-247.41	4,120,011	3,527,526		39,550		189,736,894		4,559,741
1942	-241.30	-244.20	4,062,537	3,689,212		38,583		193,583,054		3,846,160
1943	-241.05	-243.30	4,110,404	3,876,072		37,452		197,426,086		3,843,032
1944	-240.80	-242.29	4,158,556	3,979,413		37,163		201,124,486		3,698,401
1945	-240.35	-241.74	4,245,957	4,049,229		37,194		204,826,548		3,702,062
1946	-240.45	-241.37	4,226,453	4,193,474		36,569		208,555,613		3,729,065
1947	-240.45	-240.62	4,226,453	4,031,020		38,661		211,944,901		3,389,288
1948	-240.75	-241.47	4,168,221	3,959,621	39,839	40,068	225,838,558	215,769,682		3,824,781
1949	-240.20	-241.84	4,275,299	4,018,728	38,453	40,218	223,581,366	219,808,770	(2,257,192)	4,039,088
1950	-239.60	-241.53	4,393,721	4,159,157	38,100	39,615	227,665,072	224,080,539	4,083,706	4,271,770
1951	-238.30	-240.80	4,656,184	4,638,958	38,808	36,321	245,748,159	229,146,911	18,083,088	5,066,372
1952	-236.60	-238.38	5,011,896	5,131,085	36,089	33,529	245,989,087	233,972,703	240,928	4,825,793
1953	-235.75	-236.05	5,195,227	5,303,840	35,158	33,083	248,409,149	238,634,401	2,420,062	4,661,698
1954	-234.75	-235.25	5,415,635	5,339,623	34,000	33,527	250,418,960	243,468,230	2,009,810	4,833,829
1955	-234.35	-235.09	5,504,845	5,429,831	33,451	33,614	250,433,901	248,222,807	14,942	4,754,577
1956	-234.50	-234.39	5,471,340	5,277,315	34,113	35,243	253,835,602	252,946,164	3,401,701	4,723,357
1957	-234.45	-234.39	5,482,502	5,271,838	34,573	35,946	257,783,278	257,720,403	3,947,676	4,774,239
1958	-234.60	-235.21	5,449,038	5,200,545	35,769	37,036	265,073,010	261,947,401	7,289,732	4,226,998
1959	-234.30	-235.73	5,516,027	5,273,712	35,749	37,126	268,181,738	266,276,770	3,108,728	4,329,369
1960	-233.75	-235.39	5,639,482	5,464,627	35,366	36,457	271,246,460	270,945,204	3,064,722	4,668,434

Appendix B, Table B-2

Actual and Measured Salton Sea Elevation, Surface Content, Salinity, and Surface Salt Content

	Elevation (feet)		Sea Content (AF)		Salinity (ppm)		Tons of Salt In Sea		Measured Yearly Salt gain (tons)	Calculated Yearly Salt gain (tons)
	Measured	Calculated	Measured	Calculated	Measured	Calculated	Measured	Calculated		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1961	-233.35	-234.09	5,729,791	5,640,192	35,303	35,988	275,099,193	276,049,382	3,852,733	5,104,178
1962	-232.65	-233.75	5,888,900	5,878,107	35,122	35,215	281,288,725	281,518,662	6,189,532	5,469,280
1963	-231.20	-232.70	6,222,852	6,118,545	35,998	34,498	304,653,901	287,064,349	23,365,176	5,545,688
1964	-231.65	-231.65	6,072,416	6,027,121	36,727	35,621	303,309,407	291,982,560	(1,344,494)	4,918,231
1965	-232.00	-232.05	6,037,870	6,012,605	36,835	36,374	302,470,706	297,437,397	(838,701)	5,454,816
1966	-231.95	-232.11	6,049,378	6,038,445	36,339	36,866	298,966,557	302,754,173	(3,504,149)	5,316,777
1967	-231.75	-232.00	6,095,482	6,127,092	38,120	36,979	316,009,299	308,141,451	17,042,743	5,387,278
1968	-231.80	-231.61	6,083,946	6,151,469	38,540	37,454	318,886,355	313,335,986	2,877,056	5,194,535
1969	-231.95	-231.51	6,049,378	6,175,827	40,009	37,953	329,160,212	318,769,055	10,273,857	5,433,069
1970	-231.90	-231.40	6,060,894	6,138,887	38,583	38,812	318,032,538	324,034,302	(11,127,674)	5,265,246
1971	-231.65	-231.56	6,118,577	6,197,098	39,150	39,092	325,777,488	329,472,031	7,744,950	5,437,729
1972	-231.30	-231.31	6,199,630	6,298,651	39,013	39,099	328,937,979	334,930,998	3,160,490	5,458,967
1973	-231.15	-230.87	6,234,473	6,440,730	39,186	38,852	332,253,547	340,321,238	3,315,568	5,390,240
1974	-230.65	-230.27	6,351,082	6,697,767	39,183	37,958	338,442,050	345,762,389	6,188,503	5,441,151
1975	-230.05	-229.18	6,491,958	6,790,585	38,973	38,008	344,095,055	351,007,609	5,653,006	5,245,220
1976	-228.60	-228.79	6,836,710	7,000,302	38,528	37,456	358,230,479	356,592,268	14,135,424	5,584,659
1977	-228.25	-227.92	6,920,847	7,127,535	38,461	37,349	362,008,467	362,045,174	3,777,987	5,452,907
1978	-228.20	-227.40	6,932,896	7,170,987	38,141	37,654	359,621,518	367,223,591	(2,386,949)	5,178,416
1979	-227.75	-227.22	7,041,670	7,209,239	38,423	37,973	367,964,423	372,308,540	8,342,905	5,084,949
1980	-227.25	-227.06	7,163,234	7,362,830	37,616	37,570	366,455,020	376,210,088	(1,509,403)	3,901,548
1981	-227.40	-226.44	7,126,687	7,363,668	38,451	37,972	372,678,396	380,278,373	6,223,376	4,068,285
1982	-227.55	-226.43	7,090,206	7,280,477	39,897	38,823	384,714,025	384,404,566	12,035,629	4,126,193
1983	-226.65	-226.77	7,310,097	7,359,797	39,479	38,801	392,489,654	388,371,931	7,775,629	3,967,364
1984	-226.70	-226.45	7,297,818	7,435,152	40,335	38,758	400,326,160	391,909,327	7,836,505	3,537,396
1985	-226.85	-226.14	7,261,023	7,430,397	40,021	39,098	395,207,031	395,101,287	(5,119,128)	3,191,960
1986	-226.80	-226.16	7,273,280	7,401,777	40,792	39,545	403,500,650	398,074,648	8,293,618	2,973,361
1987	-227.10	-226.28	7,199,849	7,333,781	40,516	40,208	396,724,351	401,037,010	(6,776,299)	2,962,362
1988	-227.15	-226.55	7,187,637	7,313,755	42,654	40,626	416,950,775	404,093,096	20,226,424	3,056,086

Appendix B, Table B-2

Actual and Measured Salton Sea Elevation, Surface Content, Salinity, and Surface Salt Content

	Elevation (feet)		Sea Content (AF)		Salinity (ppm)		Tons of Salt In Sea		Measured Yearly Salt gain (tons)	Calculated Yearly Salt gain (tons)
	Measured	Calculated	Measured	Calculated	Measured	Calculated	Measured	Calculated		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1989	-227.40	-226.64	7,126,687	7,242,422	42,327	41,327	410,245,727	407,057,727	(6,705,047)	2,964,631
1990	-227.74	-226.93	7,044,094	7,186,319	43,582	41,967	417,514,142	410,163,427	7,268,415	3,105,701
1991	-227.53	-227.16	7,095,066	7,211,710	42,151	42,195	406,727,239	413,845,455	(10,786,903)	3,682,028
1992	-226.70	-227.05	7,297,618	7,142,171	43,773	43,003	434,448,419	417,700,863	27,721,180	3,855,408
1993	-226.78	-227.34	7,278,185	7,129,695	42,876	43,468	424,400,891	421,480,778	(10,047,528)	3,779,915
1994	-226.49	-227.39	7,349,443	7,161,671	41,771	43,657	417,511,296	425,213,753	(6,889,595)	3,732,975
1995	-226.31	-227.26	7,386,400	7,203,674	40,422	43,779	406,059,382	428,906,448	(11,451,914)	3,692,695
1996	-226.93	-227.08	7,278,185	7,159,569	42,738	44,391	423,034,921	432,233,046	16,975,539	3,326,598

Appendix B, Table B-3

	IID Net acres (1)	CVWD Net acres (2)	C Valley golf course acres (3)	Imperial Co. population (4)	Cochella Val population (5)	Beaumont Prcip. (") (6)	NIB Salin. (ppm) (7)	Reference Well Elev (8)	Loss CC (AF) (9)	Sea Surface Evapo- (AF) (10)	Banked In Sea (AF) (11)	AAC To Mexico (AF) (12)	Mexico Salinity (ppm) (13)
1905	100,000	3,000	0	6000	4,000	21	579	-140.0		921,472	0	0	2,644
1906	100,000	3,000	0	7000	4,300	22	612	-140.0		1,104,189	5,000,000	0	2,679
1907	100,000	3,000	0	8000	4,600	22.24	528	-140.0		2,828,845	1,000,000	0	2,576
1908	141,050	3,100	0	9000	4,900	17.18	669	-140.0		1,896,027	500,000	0	2,635
1909	160,470	3,200	0	10000	5,200	27.93	519	-140.0		1,745,106	250,000	0	2,129
1910	181,191	3,300	0	13,591	5,500	9.13	626	-140.0		1,631,359	250,000	0	2,557
1911	201,782	3,400	0	16,577	5,800	20.41	553	-140.0		1,529,702	250,000	0	2,135
1912	220,511	3,500	0	19,563	6,100	16.83	635	-140.0		1,449,855	250,000	0	2,517
1913	242,036	3,600	0	22,550	6,400	14.83	743	-140.0		1,378,820	250,000	0	2,852
1914	277,232	3,700	0	25,536	6,700	25.33	583	-140.0		1,318,194	250,000	0	2,236
1915	293,554	3,800	0	28,522	7,000	28.80	664	-140.0		1,257,799	250,000	0	2,637
1916	308,009	3,900	0	31,508	7,300	27.35	570	-140.0		1,113,311	250,000	0	2,555
1917	344,200	4,300	0	34,494	7,600	13.81	663	-140.0		1,066,067	250,000	0	2,375
1918	367,020	4,600	0	37,481	7,900	22.72	743	-140.0		981,140	250,000	0	2,672
1919	413,440	5,100	0	40,467	8,200	14.86	796	-140.0		924,418	0	0	3,002
1920	414,724	5,700	0	43,453	8,500	21.66	579	-140.0		888,804	(200,000)	0	2,603
1921	410,502	6,200	0	45,198	8,800	30.66	670	-140.0		920,917	(200,000)	0	3,078
1922	413,400	6,800	0	46,943	9,100	23.18	670	-140.0		914,444	(200,000)	0	2,544
1923	350,000	7,300	0	48,688	9,400	13.74	612	-140.0		871,337	(200,000)	0	2,494
1924	359,316	7,900	0	50,433	9,700	14.04	784	-140.0		895,155	(200,000)	0	2,623
1925	369,655	8,500	0	52,178	10,000	13.15	628	-140.0		876,464	(200,000)	0	2,461
1926	353,847	9,000	0	53,923	10,300	26.92	731	-141.7		868,553	(200,000)	0	3,354
1927	389,048	9,600	0	55,668	10,600	26.03	589	-139.2		915,185	(200,000)	0	2,603
1928	406,943	10,100	0	57,413	10,900	12.83	733	-139.2		947,502	(200,000)	0	2,396
1929	424,145	10,700	0	59,158	11,200	11.18	638	-140.2		928,785	(200,000)	0	2,293
1930	439,260	11,200	0	60,903	11,500	22.52	771	-142.7		953,412	(200,000)	0	2,773
1931	436,450	11,800	0	60,787	11,550	21.69	976	-147.2		977,289	(200,000)	0	3,891
1932	399,053	12,400	0	60,670	11,600	20.01	632	-154.7		973,099	(200,000)	0	2,734
1933	397,394	12,900	0	60,554	11,650	15.59	812	-159.7		990,758	(200,000)	0	2,984
1934	396,555	13,500	0	60,438	11,700	14.55	1401	-160.7		994,711	(200,000)	0	4,661
1935	403,700	14,000	0	60,322	11,750	15.47	780	-161.7		894,751	(200,000)	0	3,332

Appendix B, Table B-[illegible]

	IID Net acres (1)	CVWD Net acres (2)	C Valley golf course acres (3)	Imperial Co. population (4)	Cochella Val population (5)	Beaumont Prcip. (") (6)	NIB Salin. (ppm) (7)	Reference Well Elev (8)	Loss CC (AF) (9)	Sea Surface Evapo- (AF) (10)	Banked In Sea (AF) (11)	AAC To Mexico (AF) (12)	Mexico Salinity (ppm) (13)
1936	424,202	14,599	0	60,205	11,800	25.25	1119	-162.7		926,930	(100,000)	0	3,876
1937	430,717	15,700	0	60,089	11,850	24.23	847	-164.7		927,596	(100,000)	0	2,960
1938	416,180	16,800	0	59,973	11,900	26.84	790	-166.7		927,430	(100,000)	0	3,135
1939	419,826	17,800	0	59,856	11,950	18.65	788	-166.7		952,199	(50,000)	0	3,854
1940	415,769	18,900	0	59,740	12,000	23.77	791	-167.2		987,026	(50,000)	0	3,329
1941	399,237	19,900	0	60,034	13,500	29.96	774	-170.3		973,761	(50,000)	0	3,512
1942	382,179	21,000	0	60,329	15,000	10.72	748	-170.5		1,051,117	(50,000)	0	2,789
1943	379,947	22,100	0	60,623	16,500	27.33	688	-170.8		1,073,836	(50,000)	75000	2,894
1944	384,256	23,100	0	60,917	18,000	19.53	694	-171.8	17,616	1,100,093	(50,000)	175000	2,779
1945	393,699	24,221	52	61,211	19,500	20.20	700	-173.9	149,960	1,114,614	(50,000)	175000	2,677
1946	405,646	21,539	52	61,506	21,000	21.40	694	-174.5	128,006	1,124,424	(50,000)	175000	2,713
1947	412,083	23,558	54	61,800	22,500	7.75	710	-177.9	109,163	1,144,692	(50,000)	175000	2,353
1948	426,821	27,075	53	62,600	24,000	10.81	688	-180.9	164,800	1,121,865	0	175000	2,409
1949	428,525	34,727	53	62,800	25,500	14.62	639	-183.8	104,157	1,111,833	0	175000	2,396
1950	428,845	29,901	161	62,975	27,000	10.93	656	-184.8	188,141	1,120,138	0	185940	2,167
1951	425,000	39,315	260	62,800	29,760	15.71	686	-184.8	211,561	1,139,870	0	186834	2,681
1952	430,000	43,828	262	65,800	32,520	23.03	647	-177.0	246,935	1,207,289	0	152054	2,476
1953	445,000	46,110	269	68,100	35,280	7.55	669	-175.1	223,006	1,276,440	0	207,726	2,171
1954	441,815	52,555	374	69,300	38,040	20.28	707	-172.3	232,864	1,300,715	0	168,973	2,396
1955	450,000	47,464	367	69,700	40,800	13.11	807	-168.9	222,424	1,305,743	0	118,435	2,990
1956	450,000	48,777	431	70,300	43,560	9.63	891	-164.7	201,829	1,318,418	0	118,256	2,899
1957	450,000	49,289	415	71,700	46,320	21.08	847	-162.1	218,146	1,302,641	0	107,879	3,250
1958	450,000	46,525	627	73,100	49,080	23.12	726	-155.2	176,174	1,302,245	0	82,785	2,749
1959	433,117	52,017	844	74,000	51,840	10.77	760	-151.4	176,904	1,286,200	0	93,692	2,747
1960	430,020	51,904	846	72,105	54,600	13.32	810	-147.0	172,354	1,296,481	0	127,361	2,877
1961	430,398	49,323	1,214	73,300	57,900	8.08	1,361	-144.0	190,757	1,323,308	0	125,021	4,721
1962	425,131	49,185	1,584	73,800	61,200	12.79	1,481	-141.4	213,665	1,328,850	0	95,895	5,115
1963	427,630	49,579	1,783	74,800	64,500	16.58	1,357	-140.0	194,288	1,346,034	0	115,155	4,794
1964	422,501	54,276	1,976	75,500	67,800	13.32	1,381	-137.9	179,402	1,363,401	0	72,503	4,642
1965	423,985	55,692	2,181	75,600	71,100	23.96	1,380	-135.9	199,168	1,356,797	0	108,053	4,991
1966	424,612	52,834	2,225	76,400	74,400	15.80	1,331	-134.6	157,906	1,355,749	0	117,963	4,581
1967	436,271	48,358	2,205	75,700	77,700	20.13	1,323	-134.2	145,295	1,357,615	0	96,280	4,963

	IID Net acres (1)	CVWD Net acres (2)	C Valley golf course acres (3)	Imperial Co. population (4)	Cochella Val population (5)	Beaumont Prcip. (") (6)	NIB Salin. (ppm) (7)	Reference Well Elev (8)	Loss CC (AF) (9)	Sea Surface Evapo- (AF) (10)	Banked In Sea (AF) (11)	AAC To Mexico (AF) (12)	Mexico Salinity (ppm) (13)
1968	433,304	47,394	2,372	74,000	81,000	11.35	1,311	-134.2	150,236	1,364,018	0	101,784	4,574
1969	433,429	46,892	2,432	74,900	84,300	29.67	1,300	-134.5	163,709	1,365,779	0	69,225	4,771
1970	429,015	47,743	2,699	74,492	87,600	16.61	1,264	-136.2	132,964	1,367,538	0	85,958	4,370
1971	433,086	47,040	2,924	75,000	92,430	10.97	1,243	-134.1	142,903	1,364,870	0	85,304	4,241
1972	436,458	48,584	3,209	76,300	97,260	7.24	1,210	-135.2	156,517	1,369,075	0	95,644	4,256
1973	435,842	50,131	3,244	78,500	102,090	17.61	1,149	-135.9	150,567	1,376,409	0	113,690	3,928
1974	442,277	50,498	3,480	81,000	106,920	16.28	966	-138.3	185,080	1,386,672	0	136,227	3,431
1975	448,900	48,848	3,780	83,400	111,750	14.79	964	-137.6	191,534	1,405,237	0	104,525	3,302
1976	450,367	51,906	3,602	84,700	116,580	17.09	955	-138.2	167,488	1,411,941	0	81,790	3,874
1977	451,457	49,304	3,900	86,700	121,410	17.04	943	-139.8	164,931	1,427,088	0	46,935	3,854
1978	443,838	49,653	4,351	88,400	126,240	36.10	928	-140.9	176,718	1,436,278	0	68,189	3,675
1979	452,227	49,311	4,724	89,800	131,070	16.90	739	-141.5	200,674	1,439,416	0	48,926	2,737
1980	451,140	52,633	4,762	92,110	135,900	32.23	740	-141.8	193,231	1,442,179	0	82,295	3,049
1981	454,339	53,080	5,343	94,100	141,880	12.25	924	-141.5	73,601	1,453,273	0	94,517	3,375
1982	452,433	51,314	5,445	95,300	147,860	28.52	933	-144.4	91,234	1,453,333	0	70,556	3,784
1983	426,643	49,744	6,039	96,400	153,840	33.87	742	-147.9	66,143	1,447,325	0	120,862	3,268
1984	436,072	56,092	6,371	96,900	159,820	14.27	676	-152.2	57,123	1,453,054	0	72,613	2,695
1985	443,474	56,404	6,707	98,600	165,800	11.48	639	-157.0	45,714	1,458,496	0	97,002	2,621
1986	444,499	56,580	7,121	99,800	176,640	15.93	600	-163.6	53,583	1,458,153	0	155,323	2,400
1987	444,448	57,379	7,537	101,300	187,480	17.42	656	-165.9	47,794	1,456,086	0	127,909	2,497
1988	449,741	58,106	7,866	103,600	198,320	12.19	733	-171.6	43,873	1,451,175	0	102,353	2,557
1989	449,220	58,913	8,188	106,100	209,160	10.71	800	-174.7	52,061	1,449,728	0	100,501	2,691
1990	463,030	59,041	8,384	109,603	220,000	11.90	846	-182.8	106,034	1,444,576	0	106,799	2,953
1991	467,791	59,301	8,231	115,900	232,400	22.46	858	-188.6	43,130	1,440,524	0	123,707	3,534
1992	457,089	58,006	8,082	122,500	244,800	26.06	898	-188.9	47,087	1,442,358	0	135,716	4,035
1993	461,642	58,579	8,414	130,700	257,200	39.41	613	-187.0	45,000	1,437,335	0	143,702	2,753
1994	458,900	58,718	8,912	133,600	269,600	17.43	875	-187.0	45,000	1,436,434	0	94,874	3,202
1995	460,758	61,390	9,038	137,400	282,000	17.00	869	-187.0	45,000	1,438,744	0	69,531	3,153
1996	461,000	61,400	9,377	141,200	294,400	10.00	859	-187.0	45,000	1,441,777	0	49,235	2,796

Column (1) from IID prior to 1946, and from USBR Crop Statistics reports 1946 on.
(2) from USBR Crop Statistics reports 1948 on. Rough estimates from Nordland prior.
(3) From Tostrud July 31, 1997 memo

IID Net acres	CVWD Net acres	C Valley golf course acres	Imperial Co. population	Cochella Val population	Beaumont Prcip. (")	NIB Salin. (ppm)	Reference Well Elev	Loss CC (AF)	Sea Surface Evapo- (AF)	Banked In Sea (AF)	AAC To Mexico (AF)	Mexico Salinity (ppm)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

(4) Imperial County population from CA DWR
(5) Coachella Valley population from DWR Bulletin 132 series and Bulletin 108
(6) Beaumont precipitation from CA DWR
(7) Northerly International Boundary salinity is known only following 1958. Source for data 1959 on is International Boundary And Water Commission. Prior to 1959, salinity at NIB assumed equal to that at Imperial Dam.
(8) Reference well elevation is average of four wells 08S08E24L01S, 08S09E33N01S, 07S08E34G01S, 07S07E03A01S used, in conjuction with Salton Sea elevation, to determine subsurface flow from Coachella Valley to Salton Sea.
(9) Loss from entire Coachella Canal from CVWD
(10) Calulated Sea evaporation
(11) Model estimated water banked in Salton Sea other than 3% bank storage factor
(12) Loss, All-American Canal from Station 1117 to Drop #1, from IID records, with early years estimated.
(13) Model calculated salinity of water crossing international boundary into Salton Sea. See actual in Table B-4.

	Alamo River At Boundary			New River At Boundary			Alamo Plus New Rivers			
	AF	Tons	Tons/AF	AF	Tons	Tons/AF	AF	Tons	Tons/AF	ppm
1943	19,356	21,783	1.125	32,824	56,505	1.721	52,180	78,288	1.500	1,103
1944	12,634	15,397	1.219	27,664	54,880	1.984	40,298	70,277	1.744	1,282
1945	13,124	16,935	1.290	24,778	61,104	2.466	37,902	78,039	2.059	1,514
1946	14,411	21,298	1.478	27,639	69,994	2.532	42,050	91,292	2.171	1,596
1947	14,257	27,306	1.915	31,989	81,051	2.562	46,246	109,257	2.363	1,737
1948	9,017	17,781	1.972	38,542	85,146	2.209	47,559	102,927	2.164	1,591
1949	1,299	4,941	3.804	42,738	83,391	1.951	44,037	88,332	2.006	1,475
1950	1,393	5,323	3.821	36,992	79,500	2.149	38,385	84,823	2.210	1,625
1951	1,385	4,818	3.479	35,508	87,754	2.471	36,893	92,572	2.509	1,845
1952	1,250	4,258	3.406	35,917	71,584	1.993	37,167	75,842	2.041	1,500
1953	1,308	3,909	2.989	31,116	70,219	2.257	32,424	74,128	2.286	1,681
1954	1,431	4,401	3.075	29,505	79,900	2.708	30,936	84,301	2.725	2,004
1955	1,915	4,335	2.264	46,985	240,450	5.118	48,900	244,785	5.006	3,681
1956	2,042	5,393	2.641	76,132	431,448	5.667	78,174	436,841	5.588	4,109
1957	1,762	6,538	3.711	70,845	382,981	5.406	72,607	389,519	5.365	3,945
1958	1,991	6,895	3.463	103,983	523,580	5.035	105,974	530,475	5.006	3,681
1959	1,819	5,692	3.129	121,824	564,013	4.630	123,643	569,705	4.608	3,388
1960	1,921	6,117	3.184	121,312	596,892	4.920	123,233	603,009	4.893	3,598
1961	1,795	6,389	3.559	115,031	569,759	4.953	116,826	576,148	4.932	3,626
1962	1,705	5,908	3.465	132,179	606,163	4.586	133,884	612,071	4.572	3,362
1963	2,158	7,425	3.441	138,906	632,239	4.552	141,064	639,664	4.535	3,334
1964	1,834	6,724	3.666	105,087	671,451	6.389	106,921	678,175	6.343	4,664
1965	1,798	6,510	3.621	111,339	779,991	7.006	113,137	786,501	6.952	5,112
1966	1,545	4,930	3.191	102,958	699,160	6.791	104,503	704,090	6.738	4,954
1967	1,556	4,420	2.841	96,899	631,367	6.516	98,455	635,787	6.458	4,748
1968	1,469	4,134	2.814	106,019	735,940	6.942	107,488	740,074	6.885	5,063
1969	1,595	4,940	3.097	103,312	728,902	7.055	104,907	733,842	6.995	5,144
1970	1,645	4,988	3.032	99,671	625,962	6.280	101,316	630,950	6.228	4,579
1971	1,510	4,142	2.743	107,281	631,543	5.887	108,791	635,685	5.843	4,296
1972	1,435	4,031	2.809	111,165	670,399	6.031	112,600	674,430	5.990	4,404

	Alamo River At Boundary			New River At Boundary			Alamo Plus New Rivers			
	AF	Tons	Tons/AF	AF	Tons	Tons/AF	AF	Tons	Tons/AF	ppm
1973	1,370	3,909	2.853	117,160	689,154	5.882	118,530	693,063	5.847	4,299
1974	1,227	3,676	2.996	111,839	660,973	5.910	113,066	664,649	5.878	4,322
1975	1,568	6,783	4.326	99,791	612,112	6.134	101,359	618,895	6.106	4,490
1976	1,071	4,521	4.221	102,888	665,433	6.468	103,959	669,954	6.444	4,739
1977	1,419	6,991	4.927	107,713	674,834	6.265	109,132	681,825	6.248	4,594
1978	1,296	6,064	4.679	98,408	678,013	6.890	99,704	684,077	6.861	5,015
1979	1,053	4,290	4.074	122,934	700,553	5.699	123,987	704,843	5.685	4,180
1980	1,655	7,267	4.391	156,320	878,845	5.622	157,975	886,112	5.609	4,124
1981	2,274	10,653	4.685	155,443	972,418	6.256	157,717	983,071	6.233	4,583
1982	2,090	11,171	5.345	157,009	940,067	5.987	159,099	951,238	5.979	4,396
1983	1,909	10,377	5.436	242,606	1,259,622	5.192	244,515	1,269,999	5.194	3,819
1984	1,831	9,545	5.213	267,904	1,235,586	4.612	269,735	1,245,131	4.616	3,394
1985	1,867	8,103	4.340	260,238	1,086,665	4.176	262,105	1,094,768	4.177	3,071
1986	1,920	7,540	3.927	264,837	1,148,555	4.337	266,757	1,156,095	4.334	3,187
1987	2,058	8,737	4.245	250,862	898,076	3.580	252,920	906,813	3.585	2,636
1988	2,152	9,164	4.258	226,802	858,448	3.785	228,954	867,612	3.789	2,786
1989	1,883	8,768	4.656	153,439	550,001	3.584	155,322	558,769	3.597	2,645
1990	1,993	9,130	4.581	133,088	507,461	3.813	135,081	516,591	3.824	2,812
1991	1,951	8,168	4.187	130,775	525,716	4.020	132,726	533,884	4.022	2,958
1992	1,709	7,298	4.270	143,178	566,985	3.960	144,887	574,283	3.964	2,914
1993	1,642	7,122	4.337	190,457	578,765	3.039	192,099	585,887	3.050	2,243
1994	1,744	8,549	4.902	145,260	521,404	3.589	147,004	529,953	3.605	2,651
1995	1,233	5,729	4.646	148,762	522,968	3.515	149,995	528,697	3.525	2,592
1996	1,077	4,590	4.262	118,678	452,163	3.810	119,755	456,753	3.814	2,804

Data from Imperial Irrigation District

Appendix B. Table B-5. Salton Sea Constituent Makeup (ppm)

	Ca	Mg	Na+K	HCO3	SO4	Cl	Pan evap	pH
SS at Salton Beach								
6 6 83	1055	1184	11332	190	7724	16977	39352	8.6
11 7 83	1089	1220	9783	185	7805	14698	39416	8.6
5 7 84	1069	1208	9559	188	7779	14298	39800	8.8
11 12 84	1096	1204	7879	188	4050	14498	41036	8.8
11 11 85	1015	1200	9454	182	3884	16898	41040	8.2
5 7 87	924	1367	12863	243	1200	15700	40983	8
11 2 87	1122	1700	12679	327	10000	19100	41323	7.9
5 2 88	1248	1800	12278	146	10000	18700	42414	7.6
10 31 88	1023	2333	10427	256	10384	17500	44620	7.6
5 8 89	529	1233	15201	194	11428	17900	41823	7.5
11 4 89	497	1367	14242	306	10500	18000	43428	6.5
SS at Sandy Beach								
6 6 83	1062	1224	11211	189	7649	16977	39368	8.4
11 7 83	1096	1224	9778	190	7822	14698	39652	8.4
5 7 84	1095	1273	8434	188	7783	14298	39712	8.8
11 12 84	1149	1265	7697	188	4037	14498	41140	8.8
11 11 85	1002	1216	9670	182	3892	17248	41700	8
5 7 87	1233	1800	11654	217	11500	16600	39323	8
11 2 87	1182	2033	11328	208	10000	17200	40488	8
5 2 88	1252	2533	11756	186	9000	20700	41640	7.4
10 31 88	1042	2267	10442	322	10000	17400	42177	7.5
5 8 89	563	1433	13852	197	10714	19800	41633	7.3
11 4 89	606	1067	14966	267	10000	20600	43396	7
SS between rivers								
6 6 83	1029	1078	10367	210	7678	15158	37532	8.6
11 7 83	1082	1107	9593	204	7402	14348	35492	8.4

Appendix B, Table B-5, Salton Sea Constituent Makeup (ppm)

	Ca	Mg	Na+K	HCO3	SO4	Cl	Pan evap	pH
5 7 84	1029	1119	8815	250	7796	14298	37996	8.8
11 12 84	1069	1159	8007	200	4066	14498	38652	8.8
11 11 85	1122	1119	8893	189	3862	15998	38342	7.8
5 7 87	859	1333	5284	381	5750	9400	22941	7.7
11 2 87	1112	1867	11719	323	10000	16700	40955	7.6
5 2 88	1246	2633	11242	181	9000	20500	25079	7.5
10 31 88	876	2067	9453	223	8684	14600	36276	7.6
5 8 89	473	1033	13027	194	10000	17800	39348	7.5
11 4 89	524	1333	11612	267	8889	16400	36211	7.3
SS at Desrt Beach								
6 6 83	1049	1228	11254	190	7722	16977	39048	8.5
11 7 83	1076	1236	9725	184	7717	14698	39736	8.4
5 7 84	1082	1257	9485	190	7849	14298	39460	8.8
11 12 84	1109	1273	7725	190	4126	14498	40880	8.8
11 11 85	1015	1216	9429	182	3897	16898	41110	8
5 7 87	680	1133	10737	208	7500	15400	39233	7.9
11 2 87	965	1400	13134	336	13214	16500	40454	7.8
5 2 88	980	1667	13268	155	10000	20500	42382	7.8
5 8 89	557	1067	13294	207	10000	16600	39845	7.5
12 4 89	600	1333	13686	245	10000	17300	43471	7
SS at Bertram Sta.								
6 6 83	1136	1135	11338	190	7737	16997	39312	8.6
11 7 83	1156	1179	9777	193	7787	14698	39952	8.3
5 7 84	1162	1159	9571	193	7833	14298	40360	8.8
11 12 84	1176	1175	7858	190	4082	14498	40296	8.8
11 11 85	1082	1224	9339	182	3900	16898	40938	8
5 7 87	804	1633	12106	190	9750	17900	39009	8
11 2 87	1279	1767	9499	327	10000	14400	43316	7.6

Appendix B, Table B-5, Salton Sea Constituent Makeup (ppm)

	Ca	Mg	Na+K		HCO3	SO4	Cl		Pan evap	pH
5 2 88	1210	1433	9835		142	9500	14500		41663	8
10 31 88	1042	1533	10023		250	8684	1600		41964	7.8
5 8 89	514	1200	13830		204	10714	17100		41188	7.5
11 4 89	508	1467	12555		273	9444	19300		43833	7.1
Average all	973	1421	10777		218	7995	16108			
Tons in 1989	9432397	1376916 0	1044551 09		2114715	7749060 8	1561259 84			
Moles	235339	566352	4426064	5227756	34658	806690	4403745	5245093		
an/cat %err all	0.33%									

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12-13

IMPERIAL IRRIGATION DISTRICT
El Centro, California

Imperial County Superior Court
Case No. 52749

Eldon H. Anderson, et al.,
Plaintiffs,

V.

Imperial Irrigation District
et al., Defendants

WATER USE EFFICIENCY
IN
IMPERIAL IRRIGATION DISTRICT
AND
COACHELLA VALLEY WATER DISTRICT

BOOKMAN-EDMONSTON ENGINEERING, INC.

Glendale, California

FEBRUARY 1989

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FIGURES

Introduction

The Salton Sea is a natural sink located in the extreme southeast corner of California. It is sustained principally by irrigation return flows originating from the Imperial and Coachella Valleys and inflow from Mexico. Generally, precipitation and local runoff are minor contributors although occasional hurricane-type storms significantly affect elevation of the sea. The Imperial Valley is located generally southeasterly of the Salton Sea and the Coachella Valley is located to the northwest. An area of approximately 8,360 square miles drains to the Salton Sea and is delineated on Figure 1.

The Imperial Irrigation District (IID) was organized in 1911 and acquired control of, and operated, an extensive system of canals and laterals constructed by others. Approximately 220,000 acres were irrigated in the Imperial Valley at that time. In 1916, the District entered into an agreement with the Southern Pacific Land Company which granted the District a flowage right-of-way over Southern Pacific lands under and adjacent to the Salton Sea. The flowage right-of-way was obtained to provide for storing and evaporating excess applied irrigation water collected in open-ditch drains and discharged to the Sea.

The IID distribution system has expanded over the years and now serves an irrigated area of about 460,000 acres. Colorado River water is conveyed to the District in the All-American Canal. Most IID water flows through Drop No. 1, into the District distribution system and is conveyed to farmers through an extensive canal distribution system. Most of the main conveyance canals are not concrete-lined.

The Coachella Valley Water District (CVWD) was formed in 1918 and presently supplies irrigation water to an area of about 60,000 acres within the District's Improvement District 1. Water is diverted to the District at Drop No. 1 on the All-American Canal approximately 36 miles downstream from Imperial Dam and is conveyed to the District in the Coachella Canal. The initial 49-mile reach was replaced with a lined section in 1980. The next reach is unlined and is about 42 miles in length. The remaining 32-mile reach is lined and was part of the original project construction. The main canal conveyance and pipeline distribution systems were essentially completed by 1947. Approximately 23,000 acres were irrigated at that time.

Rising water levels of the Salton Sea in the late 1970's caused certain lands along the shoreline to be flooded. Property owners brought legal action against both Districts for damages. The action is known as the Anderson Case. A separate action was initiated in the early 1980's with the filing of an application for the Department of Water Resources (DWR) to investigate use of water by the Imperial Irrigation District. This application was filed pursuant to Water Code Section 275 and was filed by a landowner farming land adjacent to the Salton Sea. The DWR findings were presented in a report dated December 1981. In summary, the DWR found that additional water conservation measures, both structural and nonstructural could be employed to reduce inflow to the Sea from the District.

In the Anderson Case (Imperial County Superior Court Case No. 52749, Eldon H. Anderson, et al., Plaintiffs v. Imperial Irrigation District, et al., Defendants). The Court found that the return flows of both the Imperial Irrigation District and the Coachella Valley Water District contribute to rising water levels in the Salton Sea and therefore both Districts were liable for damages caused to the Plaintiffs. Discussed in this report, entitled "Water Use Efficiency In Imperial Irrigation District And Coachella Valley Water District," is an analysis of the efficiency of water use in both Districts. The focus of the report is principally on water use for agricultural purposes.

Scope and Study Objective

The scope of the investigation has been limited to a review of available data, including data obtained from the records of the Imperial Irrigation District and the Coachella Valley Water District, testimony presented before the State Water Resources Control Boards at hearings held in 1983 and in 1987, and documents and research papers prepared by various investigators that relate to the consumptive use of water in the Imperial and Coachella Valley areas. In these two areas, water use, particularly for agriculture, is concentrated within the boundaries of the IID, excluding the East Mesa area, and Improvement District 1 of CVWD. Improvement District 1 was established to fund capital improvements for importation of water from the Colorado River and most of the irrigated lands lie within its boundaries. The irrigated lands in both Districts are schematically shown on Figure 1. Water use efficiencies in these two irrigated areas are evaluated herein. No new studies were undertaken in connection with this investigation.

Water use and efficiency will be evaluated for the period from 1976 through 1980 (Anderson Case). The scope of the investigation also includes a review of available water use and efficiency data for other areas, to provide a basis for comparison.

The objective of the investigation is to compare water use efficiencies of the Imperial Irrigation District and Coachella Valley Water District and present an evaluation and analysis of the reasons for any significant differences. A further objective is to provide a compilation of available data to facilitate comparative review and aid in the evaluation of the effects of operations of the Imperial Irrigation District and the Coachella Valley Water District on inflow to the Salton Sea.

Summary of Findings

1. Presented in the following tabulation is a summary of the water use figures developed in the report:

Item	CVWD	IID
Consumptive Use 1976-80	235,000 AF/yr	1,837,000 AF/yr
Unit Amount	4.2 AF/ac	4.0 AF/ac
Leaching Requirement[(a)] 1976-80	28,000 AF/yr	219,000 AF/yr
Unit Amount	0.5 AF/ac	0.5 AF/ac
Percent of C.U.	12	12
	(in percent)	
Water Use Efficiencies 1976-80		
On-farm	65	80
Unit	73	89
District	47	69
Conveyance	66	86

(a) For an expected yield decrement of zero percent

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2. Lands utilized for agriculture in CVWD are generally coarser in soil textural class than agricultural lands in IID. Coarser textured soils have higher infiltration rates than fine textured soils.

3. Present and historical water use efficiencies in IID are higher than water use efficiencies in CVWD.

Water Utilization

The Salton Sea area is characterized as a desert environment with limited precipitation. Agricultural development in the Imperial and Coachella Valleys began in the late 1800's and is totally dependent on irrigation to meet crop water demands. Agriculturalists in the Coachella Valley relied on ground water to meet irrigation needs until 1947 when construction of the Coachella canal system was essentially complete and water from the All-American Canal could be conveyed northwesterly to the Coachella Valley. In the Imperial Valley, only limited use of ground water was made and irrigation needs were met by importation of water from the Colorado River.

The Imperial Irrigation District and the Coachella Valley Water District were formed for the purpose of providing an imported water supply to their respective service areas. Currently, essentially all lands devoted to agricultural production in both Districts receive surface supplies from the Colorado River although, in CVWD, ground water continues to be used for peaking and, to a minor extent, in areas not served by the District.

Water Supplies

The principal water source for the Imperial and Coachella Valleys is an imported supply conveyed from the Colorado River through the All-American Canal. The right to divert water from the Colorado River is covered by numerous compacts, treaties and agreements which designate the relative priorities to available Colorado River water supplies. Both Coachella Valley Water District and the Imperial Irrigation District have a relatively high priority water right based on the 1931 Seven-Party Agreement.

The Coachella Valley Water District has a contract with the California Department of Water Resources to receive water from the State Water Project (SWP), but facilities do not exist for its delivery. The District and The Metropolitan Water District of Southern California (MWD) entered into an agreement to exchange a portion of CVWD SWP supplies for MWD Colorado River supplies. Under this arrangement, over 230,000 acre-feet were exchanged in the ten-year period 1974-1983. Recent deliveries are around 50,000 acre-feet per year.

A ground water banking program has also been instigated. In essence, MWD has agreed to "predeliver" a portion of its Colorado River supply to CVWD in exchange for future deliveries of CVWD State Project supplies. Colorado River water delivered to CVWD by MWD is used for ground water recharge in the upper portion of the Coachella Valley. The program was initiated in 1986 with the delivery of nearly 224,000 acre-feet to the spreading grounds operated by CVWD. In 1987, about 281,000 acre-feet were delivered.

Surface Water. Prior to 1980, deliveries from the Colorado River system to the Coachella Valley Water District were on the order of 500,000 acre-feet per year, measured at Drop No. 1. This served an irrigated area of about 60,000 acres. Completion of the replacement of the first 49 miles of the Coachella Canal with a lined section significantly reduced the amount of water lost by seepage and subsequent diversions are on the order of 350,000 acre-feet per year. Irrigation water, not consumptively used, is collected by an extensive drainage system consisting of on-farm tile or perforated pipe drains and district-maintained pipe and open ditch drains which discharge to the Salton Sea.

Deliveries to the Imperial Irrigation District at Drop No. 1 are on the order of 2.7 million acre-feet per year and serve an irrigated area of about 460,000 acres. Water not consumptively used is collected in an open ditch drainage system and discharged to the Salton Sea. An extensive system of on-farm tile or perforated pipe drains control shallow ground water levels.

Ground Water. Utilization of ground water for agricultural or domestic purposes in the Imperial Valley is negligible. Some ground water may be used for domestic purposes, but data are not available to determine annual amounts.

Ground water underlying Coachella Valley provided the basis for the agricultural development and currently constitutes nearly twenty percent of the estimated consumptive use of the District. Extensive use of ground water is also made for golf course irrigation and for municipal and industrial (M&I) supplies for the growing population of the Coachella Valley.

The Coachella Valley Water District reports that no measurements of ground water utilization for agricultural purposes are made. However, the testimony of Mr. Tom Levy, currently General Manager and Chief Engineer of CVWD, presented before the State Water Resources Control Board in September 1983, indicates on Exhibit 7, Column 4 that deep wells provide from 40,000 to 45,000 acre-feet to meet demand within the District. Additional data were provided by CVWD for the period 1971 through 1987 and are presented in Table 1. Also presented are ground water extractions for M&I use.

Precipitation. Precipitation averages on the order of three inches per year and commonly occurs as high intensity, short-duration storms. Rainfall is generally not considered by local farmers in scheduling irrigation demands nor in projecting crop water requirements. Therefore, for purposes of this investigation, the effect of precipitation on crop water demands is considered negligible and was not included in the calculation. However, in terms of overall water balance, three inches of rainfall over 60,000 acres of agricultural lands in CVWD and 460,000 acres in IID represent volumes of 15,000 and 115,000 acre-feet, respectively.

Local Runoff. As stated in the preceding section, precipitation in the Imperial and Coachella Valleys is characterized by relatively high intensity, short-duration storms. Consequently, utilization of local surface supplies which originate from rainfall is negligible. Runoff occurring from these storms is collected in on-farm tile drains, open ditches or flows in natural channels to the Salton Sea. In the Coachella Valley, a portion of the precipitation may percolate to the underlying ground water aquifer.

Table 1

COACHELLA VALLEY WATER DISTRICT
UTILIZATION OF GROUND WATER
(Acre-feet)

	Ground Water Pumpage	
Year	Agriculture[a]	Municipal
1971	37,400	13,200
1972	40,700	13,800
1973	43,000	14,600
1974	44,500	15,600
1975	45,600	16,600
1976	42,500	17,400
1977	40,600	18,600
1978	40,000	21,400
1979	39,700	24,600
1980	40,900	30,400
1981	45,800	35,900
1982	42,200	35,800
1983	35,300	36,000
1984	37,300	43,600
1985	35,400	48,100
1986	34,900	54,500
1987	34,400	60,500
Average	40,000	29,500

(a) Estimated by CVWD as 12 percent of water received at lined section of Coachella Canal near mile point 87.

Water Demands

Water utilized for agricultural purposes constitutes the principal demand in both the Imperial and Coachella Valleys. The demands of each area will be discussed in subsequent sections of this report. Agricultural water demands are comprised of two principal components, crop consumptive use and leaching requirement. Applied water demand includes losses in the on-farm distribution system and deep percolation (in excess of amounts required for leaching).

Consumptive Use. Consumptive use is defined as the quantity of water transpired by plants, retained in plant tissue and evaporated from adjacent soil surfaces in a specific time period. It is usually expressed as depth of water per unit area. In this report, consumptive use is synonymous with evapotranspiration.

Estimates of total consumptive use for a particular area are based on the cropping pattern and crop consumptive use values. Crop consumptive use values are generally considered to be representative of long-term averages and are based on climatic factors such as hours of sunshine, temperature, wind, humidity, etc. Estimated values of evapotranspiration are generally based on field trials. Formulas are developed from field data to extrapolate the data from one area to another.

Values of crop consumptive use for the Imperial Valley were estimated by the Department of Water Resources and presented in their December 1981 report. Some of these values, specifically that of alfalfa, were reevaluated by DWR and lowered in order to provide a better correlation with evapotranspiration values obtained by others and developed through water balance calculations. Presented in Table 2 are estimated crop consumptive use values for selected crops grown in the Coachella and Imperial Valleys. These data are for comparative purposes only and generally indicate similar values for each area. As stated earlier, for purposes of estimating crop consumptive use demands, no consideration has been given for rainfall that may be utilized by the crops.

Leaching Requirement. Irrigation water applied to farms not consumptively used, may appear as surface water runoff at the end of the field (commonly called tailwater) or may percolate beyond the crop root zone. Both surface and ground water contain dissolved salts. In the case of the Colorado River water, typically the quantity of dissolved salts is on the order of 800 milligrams per liter (mg/l). As applied irrigation water is removed from the soil by the crop to satisfy consumptive use needs, the salts contained in that water are left behind and remain in the soil solution. The concentration of the soil solution (generally expressed in milligrams per liter of total dissolved solids) must be controlled in order to maintain agricultural productivity. The amount of water needed to leach accumulated salts from the soil in order to maintain a reasonable concentration of the salts in the soil water is called the leaching fraction and is generally expressed as a percent of consumptive use. The two principal factors that determine the leaching fraction are the tolerance of the crop to salts and the

Table 2

CROP CONSUMPTIVE USE
(Acre-feet Per Acre)

	Crop Consumptive Use	
Crop	CVWD[a]	IID[b]
Alfalfa	5.5	5.4[c]
Barley	2.0	1.8
Cotton	3.4	3.6
Lettuce	1.1	1.4
Carrots	1.2	1.3
Citrus	5.1[d]	3.8

(a) From CVWD document identified as CV 19
(b) From IID
(c) From DWR
(d) Value inconsistent with other data. A value of 3.8 acre-feet per acre per year was used to estimate total consumptive use of CVWD.

salinity of the irrigation water. Leaching requirements for each crop, based on homogeneous soil conditions, are presented later and are derived from crop tolerance tables presented in Irrigation and Drainage Paper #29, "Water Quality for Agriculture" prepared by the Food and Agriculture Organization of the United Nations, Rome 1976. Values presented in Table 5, "Crop Tolerance Table" of the FAO report, were used in the determination of leaching fractions for this report. Appendix A is a copy of the crop tolerance table used.

It is noted that figures presented are intended to be guidelines for general evaluations of leaching requirements and, although they can be used for preliminary determinations, additional studies may be required for specific areas. Use of general guidelines for purposes of comparing leaching requirements of CVWD with IID is reasonable in the determination of the order of magnitude of the amount of water required to maintain favorable growing conditions. The electrical conductivity of the soil water that would be expected to have no effect on crop yields was used to determine the leaching requirement for each crop (i.e., zero percent yield reduction).

Comparison of the leaching requirement for the Imperial Valley and the Coachella Valley is focused on the cropping pattern of each area since the basic water source is the same for each area (i.e., Colorado River). The average leaching requirement for the Imperial Valley and the Coachella Valley is on the order of 12 to 13 percent of consumptive use.

Water Use Efficiency

"Water use efficiency" is a term used to describe the relative effectiveness of water delivery/distribution systems and can be expressed in different ways. Terms used to describe categories of water use efficiency are described in the following sections.

On-farm Irrigation Efficiency. On-farm irrigation efficiency is one of the most common terms utilized to describe the effectiveness of the farmer's use of water for irrigation. On-farm irrigation efficiency is affected by the method of irrigation as well as other farm management practices. It is defined as the ratio of the volume of water used for consumptive use in cropped areas to the volume of water delivered to the farm, commonly called "applied water."

Unit Irrigation Efficiency. Unit irrigation efficiency is similar to on-farm irrigation efficiency, except that water required for leaching is considered a beneficial use and is included in the numerator to compute the ratio. In other words, unit irrigation efficiency is the ratio of the volume of water used for consumptive use in cropped areas plus that amount of water necessary to maintain favorable salt balance in the root zone of the crop (leaching requirement) to the volume of water delivered to the farm (applied water).

District Irrigation Efficiency. District irrigation efficiency includes losses incurred in the conveyance of water from the district diversion point to the field. It is defined as the ratio of the volume of water used for consumptive use in cropped areas to the volume of water delivered to the irrigation district service area conveyance system. In the case of the Imperial Irrigation District and the Coachella Valley Water District, the delivery point for purposes of this report is considered to be Drop No. 1 on the All-American Canal.

As stated above, losses in conveyance, either through evaporation or seepage from the canal system, are considered in district irrigation efficiency. The term "conveyance system efficiency" is an expression of this loss and is the ratio of the volume of water delivered to the farm headgate to the volume of water introduced into the conveyance system.

Factors Affecting Water Use Efficiency

The efficiency of water use, whether at the on-farm level or at the level of a large district distribution system, is dependent on many factors, some of which are not within the control of the operators of the system. Included in this category are climatic factors, physical characteristics of the soils being irrigated and through which the distribution system is constructed, and the distance between the source of the water supply and the point of use. Factors over which the District Managers and farm operators of the respective systems can exert control through their management decisions include crop type and irrigation system at the on-farm level and type of distribution system and operational procedures with regard to water deliveries at the District level. Precipitation in both IID and CVWD is generally not considered when the farmers schedule water, but, from a district operational standpoint, can interfere with deliveries as runoff flows into the distribution system causing higher water levels or scheduled head changes cannot be made due to wet conditions of roads and fields. In most cases, economic factors underlie management decisions that can affect water use efficiencies at both the on-farm and District levels.

Analyses of water use efficiency is one of the tools utilized by management to evaluate the relative economics and benefits possible from a proposed improvement to the system. However, when water use efficiency for one district is compared to that of another district, the evaluation must go beyond the arithmetic which could lead one to conclude that a district with an efficiency of 70 percent had better management than a district with a 50 percent efficiency. Stated another way, factors affecting irrigation efficiency must be carefully evaluated and reviewed before concluding that a district is managed better than another district simply because of a higher district irrigation efficiency. Set forth in the following sections are evaluations of the water use efficiency of the Imperial Irrigation District and the Coachella Valley Water District.

Coachella Valley Water District

The Coachella Valley Water District was formed in 1918 and presently supplies irrigation water to an area of about 60,000 acres within the District's Improvement District 1. Water is diverted to the District at Drop No. 1 on the All-American Canal approximately 36 miles downstream from Imperial Dam. Water is conveyed to the District in the Coachella Canal. The first 49 miles was replaced with a lined section in 1980. The next reach is an unlined section 42 miles in length and the remaining 32 miles was lined as part of the original construction. The original system was essentially completed in 1947. At that time approximately 23,000 acres were irrigated. By 1954 the distribution system was completed and now consists of about 500 miles of pipeline. Water delivery to farms from the District are measured by meters installed at each turnout. An extensive drainage system consisting of about 165 miles of pipelines and about 21 miles of open ditches are also maintained by the District. Most of the inflow to the District drainage system is collected by on-farm tile drains which discharge to the District system. The District reports that there are about 2,300 miles of on-farm drain lines.

The District also reports that about 4,000 acres of agricultural land within Improvement District 1 rely on ground water. Data were not available to determine if the 4,000 acres were totally dependent on ground water or if ground water extractions were utilized to supplement surface supplies in peak demand months. Estimates of annual ground water extractions were presented in Table 1.

The total consumptive use was calculated using crop consumptive use factors and the cropping patterns for the 1976-1980 period. The results are presented in Table 3. Deliveries to farms are also shown for each year and are based on data provided by the District.

Average annual crop water requirements in Coachella Valley are published by CVWD in the pamphlet entitled "Water and the Coachella Valley." These crop values (expressed in acre-feet per acre) were used to estimate total water requirement and the computed values were compared with actual farm deliveries reported by District representatives. The results are tabulated in Table 4. It is noted that computed water deliveries exceed deliveries reported by CVWD. The reason for this difference cannot be explained with available data.

Calculations of the amount of water required to flush accumulated salts for favorable crop production were also made and are presented in Table 5. These calculations are based on sufficient leaching, such that there is no reduction in crop yields. Calculations based on an allowable yield reduction of ten percent reduces the amount of leaching water required by an average of about 10,000 acre-feet or about 30 percent. Presented in Table 6 is a summary of calculated leaching requirements for expected yield decrements of zero and 10 percent. The average salinity of the Colorado River at Imperial Dam is also shown. Estimated leaching requirements ignore use of ground

Table 3

COACHELLA VALLEY WATER DISTRICT
TOTAL CONSUMPTIVE USE
1976-1980

Truck Crops	Crop ET (AF/ac)	1976 Area (ac)	1976 Water (AF)	1977 Area (ac)	1977 Water (AF)	1978 Area (ac)	1978 Water (AF)	1979 Area (ac)	1979 Water (AF)	1980 Area (ac)	1980 Water (AF)	1976-80 Avg Area (ac)	1976-80 Avg Water (AF)
Asparagus	5.5	300	1,650	300	1,650	389	2,140	571	3,141	836	4,598	479	2,636
Beans	1.7	533	906	411	699	387	658	398	677	381	648	422	718
Broccoli	1.4	182	255	264	370	412	577	915	1,281	610	854	477	667
Cabbage	1.4	472	661	442	619	492	689	317	444	420	588	429	600
Carrots	1.2	6,412	7,694	5,294	6,353	5,660	6,792	5,207	6,248	5,129	6,155	5,540	6,648
Corn (sweet)	2.6	6,312	16,411	6,073	15,790	6,512	16,931	4,908	12,761	4,997	12,992	5,760	14,977
Cucumber	3.2	221	707	199	637	5	16	30	96	55	176	102	326
Lettuce	1.1	430	473	616	678	486	535	1,191	1,310	1,004	1,104	745	820
Cantaloupe	2.9	48	139	53	154	15	44	100	290	68	197	57	165
Honeydew	2.9	14	41	20	58	36	104	81	235	0	0	30	88
Watermelon	2.1	0	0	0	0	0	0	140	294	119	250	52	109
Onion (dry)	2.1	270	567	228	479	245	515	213	447	201	422	231	486
Onion (green)	1.1	302	332	153	168	105	116	123	135	72	79	151	166
Peas	1.5	36	54	5	8	8	12	11	17	10	15	14	21
Peppers	2.8	235	658	142	398	217	608	260	728	333	932	237	665
Squash	3.2	528	1,690	615	1,968	598	1,914	479	1,533	435	1,392	531	1,699
Sweet potatoes	3.1	0	0	0	0	0	0	0	0	0	0	0	0
Tomatoes(fresh)	1.8	61	110	94	169	15	27	8	14	30	54	42	75
Other Veg.	3.1	1,723	5,341	1,360	4,216	1,904	5,902	2,427	7,524	2,037	6,315	1,890	5,860
Nursery	3.3	234	772	225	743	224	739	248	818	232	766	233	768
Total Truck		18,313	38,461	16,494	35,157	17,710	38,319	17,627	37,993	16,969	37,537	17,422	37,493
AF/ac			2.1		2.1		2.2		2.2		2.2		2.2
Field Crops													
Grain	2.0	2,627	5,254	973	1,946	845	1,690	745	1,490	2,500	5,000	1,538	3,076
Alfalfa	5.5	3,564	19,602	4,453	24,492	5,139	28,265	4,921	27,066	5,503	30,267	4,716	25,938
Other Hay	3.9	2,020	7,878	80	312	110	429	0	0	783	3,054	599	2,335
Pasture	6.8	2,646	17,993	1,596	10,853	1,445	9,826	1,428	9,710	1,484	10,091	1,720	11,695
Sorghum	4.2	205	861	40	168	228	958	70	294	140	588	137	574
Cotton	3.4	1,725	5,865	5,400	18,360	4,200	14,280	3,500	11,900	4,400	14,960	3,845	13,073
Sugar Beets	4.0	0	0	0	0	0	0	0	0	0	0	0	0
Total Field		12,787	57,453	12,542	56,131	11,967	55,448	10,664	50,460	14,810	63,960	12,555	56,690
AF/ac			4.5		4.5		4.6		4.7		4.3		4.5
Fruit Crops													
Grapefruit	3.8	8,690	33,022	8,526	32,399	8,325	31,635	8,330	31,654	8,465	32,167	8,467	32,175
Lemons	3.8	2,542	9,660	2,410	9,158	2,450	9,310	2,509	9,534	2,131	8,098	2,408	9,152
Oranges	3.8	6,142	23,340	5,080	19,304	5,115	19,437	4,385	16,663	4,008	15,230	4,946	18,795
Dates	5.7	4,012	22,868	4,093	23,330	3,869	22,053	4,506	25,684	4,724	26,927	4,241	24,172
Grapes	3.3	7,479	24,681	7,208	23,786	7,465	24,635	7,920	26,136	8,526	28,136	7,720	25,475
Other Fruit	4.3	154	662	172	740	172	740	387	1,664	335	1,441	244	1,049
Pecans	4.0	34	136	27	108	0	0	0	0	29	116	18	72
Total Fruit		29,053	114,369	27,516	108,825	27,396	107,810	28,037	111,335	28,218	112,115	28,044	110,891
AF/ac			3.9		4.0		3.9		4.0		4.0		4.0
Crops Harvested	—	60,153	210,283	56,552	200,113	57,073	201,577	56,328	199,788	59,997	213,612	58,021	205,075
Less Double Crop	—	8,247	—	7,248	—	7,420	—	7,017	—	7,364	—	7,459	—
Producing Area	—	51,906	—	49,304	—	49,653	—	49,311	—	52,633	—	50,729	—
Soil Building	5.5	2,838	15,609	3,089	16,990	3,384	18,612	3,487	19,179	3,167	17,419	3,193	17,562
Not Harvested	4.5	1,416	6,372	3,218	14,481	3,224	14,508	3,414	15,363	2,079	9,356	2,670	12,016
Total Water Using		56,160	232,264	55,611	231,584	56,261	234,697	56,212	234,330	57,879	240,387	56,766	234,652
AF/ac			4.1		4.2		4.2		4.2		4.2		4.2
CVWD Water Delivery (a)			334,000		323,000		317,000		311,000		322,000		321,400

(a) From declaration by Lowell Weeks. Does not include ground water pumpage.
(b) Crop ET values based on CV 19

Table 4

COACHELLA VALLEY WATER DISTRICT
FARM DELIVERIES
(Acre-feet in thousands)

Year	Farm Deliveries		Difference	Ground Water Pumpage for Agriculture
	Calculated	Reported		
(1)	(2)	(3)	(4)	(5)
1976	388	334	54	42
77	380	323	57	41
78	385	317	68	40
79	386	311	75	40
80	395	322	73	41
Avg. 1976-80	387	321	66	41

Notes:
- Col 2 - Derived from irrigated area and unit water requirements
- Col 3 - From CVWD
- Col 4 - Col 2-Col 3
- Col 5 - From Table 1

Table 5

COACHELLA VALLEY WATER DISTRICT CALCULATED CROP LEACHING REQUIREMENTS FOR AN EXPECTED YIELD DECREMENT OF ZERO PERCENT 1976-1980

		1976		1977		1978		1979		1980		1976-80 Avg	
Truck Crops	Crop ET (AF/ac)	Area (ac)	L.Water (AF)	Area (ac)	L.Water (AF)	Area (ac)	L.Water (AF)	Area (ac)	L.Water (AF)	Area (ac)	L.Water (AF)	Area (ac)	L.Water (AF)
Asparagus	5.5	300	430	300	427	389	547	571	788	836	1065	479	651
Beans	1.7	533	479	411	366	387	339	398	340	381	293	422	363
Broccoli	1.4	182	29	264	41	412	64	915	140	610	87	477	72
Cabbage	1.4	472	132	442	123	492	135	317	86	420	105	429	116
Carrots	1.2	6,412	4065	5,294	3331	5,660	3499	5,207	3140	5,129	2784	5,540	3,364
Corn (sweet)	2.6	6,312	3554	6,073	3401	6,512	3603	4,908	2668	4,997	2519	5,760	3,149
Cucumber	3.2	221	91	199	82	5	2	30	12	55	21	102	42
Lettuce	1.1	430	155	616	220	486	171	1,191	411	1,004	318	745	255
Cantaloupe	2.9	48	21	53	23	15	7	100	43	68	27	57	24
Honeydew	2.9	14	6	20	9	36	16	81	35	0	0	30	13
Watermelon	2.1	0	0	0	0	0	0	140	43	119	34	52	15
Onion (dry)	2.1	270	212	228	178	245	189	213	160	201	138	231	175
Onion (green)	1.1	302	124	153	63	105	42	123	49	72	26	151	61
Peas	1.5	36	29	5	4	8	6	11	8	10	7	14	11
Peppers	2.8	235	171	142	103	217	155	260	183	333	216	237	166
Squash	3.2	528	440	615	510	598	489	479	385	435	323	531	429
Sweet potatoes	3.1	0	0	0	0	0	0	0	0	0	0	0	0
Tomatoes(fresh)	1.8	61	14	94	22	15	3	8	2	30	6	42	9
Other Veg.	3.1	1,723	1391	1,360	1092	1,904	1509	2,427	1888	2,037	1463	1,890	1,469
Nursery	3.3	234	201	225	192	224	189	248	205	232	177	233	193
Total Truck		18,313	11,544	16,494	10,187	17,710	10,965	17,627	10,586	16,969	9,609	17,423	10,578
Leaching(AF/ac)			0.6		0.6		0.6		0.6		0.6		0.6
Field Crops													
Grain	2.0	2,627	246	973	91	845	78	745	68	2,500	215	1,538	140
Alfalfa	5.5	3,564	3388	4,453	4212	5,139	4805	4,921	4526	5,503	4714	4,716	4,329
Other Hay	3.9	2,020	1362	80	54	110	73	0	0	783	476	599	393
Pasture	6.8	2,646	3110	1,596	1867	1,445	1671	1,428	1624	1,484	1572	1,720	1,969
Sorghum	4.2	205	63	40	12	228	70	70	21	140	40	137	41
Cotton	3.4	1,725	210	5,400	654	4,200	504	3,500	414	4,400	492	3,845	455
Sugar Beets	4.0	0	0	0	0	0	0	0	0	0	0	0	0
Total Field		12,787	8,379	12,542	6,890	11,967	7,201	10,664	6,653	14,810	7,509	12,554	7,326
Leaching(AF/ac)			0.7		0.5		0.6		0.5		0.5		0.6
Fruit Crops													
Grapefruit	3.8	8,690	2882	8,526	2817	8,325	2725	8,330	2690	8,465	2579	8,467	2,739
Lemons	3.8	2,542	843	2,410	796	2,450	802	2,509	810	2,131	649	2,408	780
Oranges	3.8	6,142	2037	5,080	1678	5,115	1674	4,385	1416	4,008	1221	4,946	1,605
Dates	5.7	4,012	1685	4,093	1712	3,869	1602	4,506	1840	4,724	1814	4,241	1,731
Grapes	3.3	7,479	1395	7,208	1340	7,465	1375	7,920	1440	8,526	1465	7,720	1,403
Other Fruit	4.3	154	37	172	42	172	41	387	92	335	75	244	57
Pecans	4.0	34	14	27	11	0	0	0	0	29	11	18	7
Total Fruit		29,053	8,893	27,516	8,396	27,396	8,219	28,037	8,288	28,218	7,814	28,044	8,322
Leaching(AF/ac)			0.3		0.3		0.3		0.3		0.3		0.3
Crops Harvested	—	60,153	28,816	56,552	25,473	57,073	26,385	56,328	25,527	59,997	24,932	58,021	26,227
Less Double Crop	—	1	—	7,248	--	7,420	—	7,017	—	7,364	--	5,810	—
Producing Area	--	60,152	--	49,304	--	49,653	—	49,311	--	52,633	—	52,211	—
Soil Building		2,838	940	3,089	1,070	3,384	1,238	3,487	1,219	3,167	1,030	3,193	1,099
Not Harvested		1,416	469	3,218	1,115	3,224	1,180	3,414	1,194	2,079	676	2,670	927
Total Leaching		64,406	30,225	55,611	27,658	56,261	28,803	56,212	27,940	57,879	26,638	58,074	28,253
Leaching(AF/ac)			0.5		0.5		0.5		0.5		0.5		0.5
Colorado River Salinity (mg/l)			822		819		812		802		760		

Table 6

COACHELLA VALLEY WATER DISTRICT
SUMMARY OF DISTRICT LEACHING REQUIREMENTS
(Acre-feet in thousands)

Year	Leaching Requirement for[a] Expected Yield Decrement of 0%	10%	Salinity of Colorado River @ Imperial Dam (mg/l)(b)
1976	30	19	822
77	28	18	819
78	29	18	812
79	28	18	802
80	27	17	760
Avg. 1976-80	28	18	--
Percent of ET	12	8	

(a) Appendix A
(b) USBR data

water which, compared to Colorado River water, is of lower or equal salinity.

The theoretical leaching requirement is on the order of 30,000 acre-feet per year, based on the guidelines presented in the FAO publication. Comparison of surface deliveries to farms, as reported by CVWD and summarized in Table 4, with estimates of consumptive use shown in Table 3, indicates an average difference of about 90,000 acre-feet for the 1976-1980 period. All water applied in excess of consumptive use may not contribute to leaching but, in CVWD, most does since surface runoff is kept to a minimum, according to District representatives. Therefore, even if calculations of leaching requirements are understated by a factor of three using the FAO guidelines, increasing the amount of applied water for additional leaching would not significantly affect crop yields. In fact, reducing average applied water by from 60,000 to 80,000 acre-feet per year would not result in reduced crop yields (from present levels) due to salinity buildup. However, yields could be negatively affected if crops were subjected to moisture stress from inadequate or infrequent irrigations.

The water use efficiencies of the Coachella Valley Water District were determined for each year and are presented in Table 7. Estimated ground water pumpage, based on data provided by CVWD and discussed earlier, is included in the estimate of total diversion as noted in the two tables.

Table 7

COACHELLA VALLEY WATER DISTRICT
WATER USE EFFICIENCY
(1976-1980)

Item	1976 Amount (TAF)	1976 (AF/ac)	1977 Amount (TAF)	1977 (AF/ac)	1978 Amount (TAF)	1978 (AF/ac)	1979 Amount (TAF)	1979 (AF/ac)	1980 Amount (TAF)	1980 (AF/ac)	1976-80 Avg. Amount (TAF)	1976-80 Avg. (AF/ac)
(1) Irrigated Area (1,000 ac.)	56.2	--	55.6	--	56.3	--	56.2	--	57.9	--	56.4	--
(2) Diversion at Drop No. 1	505.7	9.0	493.5	8.9	492.7	8.8	515.3	9.2	516.6	8.9	504.8	8.9
(3) Total Diversion (a)	548.2	9.8	534.1	9.6	532.7	9.5	555.0	9.9	557.5	9.6	545.5	9.7
(4) Surface Deliveries (b)	334.0	5.9	323.0	5.8	317.0	5.6	311.0	5.5	322.0	5.6	321.4	5.7
(5) Ground Water Pumpage	42.5	0.8	40.6	0.7	40.0	0.7	39.7	0.7	40.9	0.7	40.7	0.7
(6) Delivery to Farms	376.5	6.7	363.6	6.5	357.0	6.3	350.7	6.2	362.9	6.3	362.1	6.4
(7) Consumptive Use	232.3	4.1	231.6	4.2	234.7	4.2	234.3	4.2	240.4	4.2	234.7	4.2
(8) Leaching Requirement @ 0%	30.4	0.5	27.7	0.5	28.8	0.5	27.9	0.5	26.6	0.5	28.3	0.5
(9) Total Beneficial Use	262.7	4.7	259.3	4.7	263.5	4.7	262.2	4.7	267.0	4.6	262.9	4.7
Water Use Efficiencies:												
Conveyance System	68.7	--	68.1	--	67.0	--	63.2	--	65.1	--	66.4	--
On-farm Irrigation	61.7	--	63.7	--	65.7	--	66.8	--	66.2	--	64.8	--
District Irrigation	45.9	--	46.9	--	47.6	--	45.5	--	46.5	--	46.5	--
Unit Irrigation	69.8	--	71.3	--	73.8	--	74.8	--	73.6	--	72.6	--

(a) Includes ground water pumpage.
(b) CVWD estimate of delivery of Colorado River water to farms.

Imperial Irrigation District

The Imperial Irrigation District was formed in 1911 under the California Irrigation District Act. In 1916, the District became the holder of the rights to Colorado River water previously held by a private development company and operated an extensive water distribution system constructed by the company and others.

The All-American Canal conveys water from the Colorado River to the East Highline Canal, the Central Main Canal and to the Westside Main Canal. Water is diverted from these main conveyance canals to an extensive system of smaller canals and laterals which deliver the water to farm headgates. Several small regulating reservoirs have been constructed to manage mismatches in water ordered and water delivered. IID operates and maintains over 1,600 miles of conveyance and distribution facilities including the All-American Canal. Approximately 900 miles of the system is concrete lined, 9 miles are in pipeline, and the remaining canal is an earth section. Water delivery to farms is through gated delivery structures. The amount delivered is determined by measuring the head difference through an orifice (for rate of flow) and time required to accomplish the delivery.

Irrigation water applied in excess of consumptive use is collected by on-farm tile drains and tailwater return boxes which discharge to the drainage system maintained by the District. There are nearly 1,400 miles of open-ditch drain and 100 miles of pipeline drains maintained by the District.

Operational losses from the canal distribution system also enter the drain system which discharges to the Salton Sea.

The total consumptive use for IID was estimated using crop consumptive use factors and the cropping patterns for the 1976-1980 period. The results are presented in Table 8. Deliveries to farms are also shown for each year and are based on data provided by the District.

The amounts of water required to maintain favorable crop production conditions were also calculated and are presented in Table 9. These calculations are based on sufficient leaching, such that there is no reduction in crop yields. Calculations based on an allowable yield reduction of ten percent reduces the amount of leaching water required by an average of about 75,000 acre-feet or about 30 percent. Presented in Table 10 is a summary of calculated leaching requirements for expected yield decrements of zero and 10 percent. The average salinity of the Colorado River at Imperial Dam is also shown.

The theoretical leaching requirement is on the order of 220,000 acre-feet per year, based on the guidelines presented in the FAO publication. Comparisons of surface deliveries to farms with estimates of consumptive use indicate a difference of about 476,000 acre-feet for the 1976-1980 period. Water applied in excess of consumptive use flows to the drains as tailwater or appears as deep percolation (leaching). Previous studies estimate that tailwater may account for about one-half of total irrigation return flows. Therefore, roughly speaking, the theoretical leaching requirement estimated using the FAO guidelines is accomplished in actual practice.

Table 8

IMPERIAL IRRIGATION DISTRICT
TOTAL CONSUMPTIVE USE
1976-1980

Truck Crops	Crop ET (AF/ac)	1976 Area (ac)	1976 Water (AF/ac)	1977 Area (ac)	1977 Water (AF/ac)	1978 Area (ac)	1978 Water (AF/ac)	1979 Area (ac)	1979 Water (AF/ac)	1980 Area (ac)	1980 Water (AF/ac)	1976-80 Avg Area (ac)	1976-80 Avg Water (AF/ac)
Alfalfa	5.4	134,400	725,760	141,000	761,400	143,000	772,200	151,800	819,720	150,500	812,700	144,140	778,356
Barley	1.8	3,500	6,300	7,000	12,600	7,500	13,500	4,000	7,200	2,000	3,600	4,800	8,640
Cotton	3.6	67,000	241,200	138,000	496,800	61,500	221,400	83,000	298,800	83,500	300,600	86,600	311,760
Sorghum, Grain	2.5	17,000	42,500	7,000	17,500	15,000	37,500	8,500	21,250	4,000	10,000	10,300	25,750
Sudan	2.5	26,000	65,000	6,500	16,250	12,000	30,000	24,500	61,250	20,500	51,250	17,900	44,750
Sugar Beets	3.7	74,000	273,800	60,000	222,000	36,500	135,050	48,000	177,600	37,000	136,900	51,100	189,070
Wheat	2.1	146,500	307,650	67,500	141,750	135,500	284,550	100,000	210,000	142,000	298,200	118,300	248,430
Misc. Field Crops	2.5	13,500	33,750	12,000	30,000	20,000	50,000	14,500	36,250	8,500	21,250	13,700	34,250
Melons	2.3	12,500	28,750	15,000	34,500	17,000	39,100	15,500	35,650	17,000	39,100	15,400	35,420
Lettuce	1.4	44,500	62,300	39,500	55,300	41,500	58,100	43,500	60,900	44,500	62,300	42,700	59,780
Carrots	1.3	7,500	9,750	4,500	5,850	6,500	8,450	9,000	11,700	7,500	9,750	7,000	9,100
Tomatoes	2.3	3,500	8,050	4,500	10,350	3,500	8,050	3,000	6,900	1,500	3,450	3,200	7,360
Misc. Garden Crops	1.7	11,500	19,550	11,000	18,700	16,500	28,050	18,000	30,600	16,500	28,050	14,700	24,990
Citrus	3.8	2,000	7,600	2,000	7,600	2,000	7,600	1,500	5,700	1,500	5,700	1,800	6,840
Misc. Permanent Crops	4.2	14,000	58,800	12,500	52,500	11,500	48,300	12,000	50,400	12,500	52,500	12,500	52,500
Totals		577,400	1,890,760	528,000	1,883,100	529,500	1,741,850	536,800	1,833,920	549,000	1,835,350	544,140	1,836,996
Net Irrigated (a)		458,500		460,000		452,000		460,000		460,500		458,200	
AF/ac			4.1		4.1		3.9		4.0		4.0		4.0
IID Water Delivery			2,323,000		2,254,000		2,226,000		2,375,000		2,324,000		2,300,400

(a) Difference between total and net primarily due to double cropping.

Table 9

IMPERIAL IRRIGATION DISTRICT
CALCULATED CROP LEACHING REQUIREMENTS FOR AN
EXPECTED YIELD DECREMENT OF ZERO PERCENT
1976-1980

Crop	Crop ET (AF/ac)	1976 Area (ac)	1976 L.Water (AF/ac)	1977 Area (ac)	1977 L.Water (AF/ac)	1978 Area (ac)	1978 L.Water (AF/ac)	1979 Area (ac)	1979 L.Water (AF/ac)	1980 Area (ac)	1980 L.Water (AF/ac)	1976-80 Avg Area (AF/ac)	1976-80 Avg L.Water (ac)
Alfalfa	5.4	134,400	125,400	141,000	131,000	143,000	131,300	151,800	137,100	150,500	126,600	144,140	130,280
Barley	1.8	3,500	200	7,000	400	7,500	500	4,000	200	2,000	100	4,800	280
Cotton	3.6	67,000	8,600	138,000	17,700	61,500	7,800	83,000	10,400	83,500	9,900	86,600	10,880
Sorghum, Grain	2.5	17,000	3,100	7,000	1,300	15,000	2,700	8,500	1,500	4,000	700	10,300	1,860
Sudan	2.5	26,000	7,300	6,500	1,800	12,000	3,300	24,500	6,700	20,500	5,200	17,900	4,860
Sugar Beets	3.7	74,000	10,800	60,000	8,800	36,500	5,300	48,000	6,800	37,000	5,000	51,100	7,340
Wheat	2.1	146,500	14,400	67,500	6,600	135,500	13,100	100,000	9,600	142,000	12,800	118,300	11,300
Misc. Field Crops	2.5	13,500	2,500	12,000	2,200	20,000	3,600	14,500	2,600	8,500	1,400	13,700	2,460
Melons	2.3	12,500	4,400	15,000	5,200	17,000	5,900	15,500	5,300	17,000	5,400	15,400	5,240
Lettuce	1.4	44,500	20,400	39,500	18,000	41,500	18,600	43,500	19,100	44,500	17,900	42,700	18,800
Carrots	1.3	7,500	5,200	4,500	3,100	6,500	4,400	9,000	5,900	7,500	4,400	7,000	4,600
Tomatoes	2.3	3,500	1,000	4,500	1,300	3,500	1,000	3,000	900	1,500	400	3,200	920
Misc. Garden Crops	1.7	11,500	4,200	11,000	4,000	16,500	6,000	18,000	6,400	16,500	5,400	14,700	5,200
Citrus	3.8	2,000	1,600	2,000	1,600	2,000	1,600	1,500	1,200	1,500	1,100	1,800	1,420
Misc. Permanent Crops	4.2	14,000	15,300	12,500	13,600	11,500	12,300	12,000	12,600	12,500	12,200	12,500	13,200
Totals		577,400	224,400	528,000	216,600	529,500	217,400	536,800	226,300	549,000	208,500	544,140	218,640
Net Irrigated (a)		458,500		460,000		452,000		460,000		460,500		458,200	
Leaching(AF/ac)			0.5		0.5		0.5		0.5		0.5		0.5
Colorado River Salinity (mg/l)			822		819		812		802		760		

(a) Difference between total and net primarily due to double cropping.

Table 10

IMPERIAL IRRIGATION DISTRICT
SUMMARY OF DISTRICT-LEACHING REQUIREMENTS
(Acre-feet in thousands)

Year	Leaching Requirement for[a] Expected Yield Decrement of 0%	10%	Salinity of Colorado River @ Imperial Dam[b] (mg/l)
1976	224	150	822
77	217	143	819
78	217	140	812
79	226	144	802
80	208	134	760
Avg. 1976-80	218	142	--
Percent of ET	12	8	

(a) Appendix A
(b) USBR

The water use efficiencies of the Imperial Irrigation District were determined for each year of the study period and are presented in Table 11.

Table 11

IMPERIAL IRRIGATION DISTRICT
WATER USE EFFICIENCY
1976-1980

Item	1976 Amount (TAF)	1976 (AF/ac)	1977 Amount (TAF)	1977 (AF/ac)	1978 Amount (TAF)	1978 (AF/ac)	1979 Amount (TAF)	1979 (AF/ac)	1980 Amount (TAF)	1980 (AF/ac)	1976-80 Avg. Amount (TAF)	1976-80 Avg. (AF/ac)
(1) Irrigated Area (1,000 ac.)	458.5	--	460.0	--	452.0	—	460.0	--	460.5	--	458.2	--
(2) Diversion at Drop No. 1	2,784.0	6.1	2,693.0	5.9	2,672.0	5.9	2,803.0	6.1	2,769.0	6.0	2,744.2	6.0
(3) Diversion for M & I Use	60.0	0.1	59.0	0.1	64.0	0.1	66.0	0.1	64.0	0.1	62.6	0.1
(4) Diversion for Ag. Use	2,724.0	5.9	2,634.0	5.7	2,608.0	5.8	2,737.0	6.0	2,705.0	5.9	2,681.6	5.9
(5) Delivery to Farms	2,323.0	5.1	2,254.0	4.9	2,226.0	4.9	2,375.0	5.2	2,324.0	5.0	2,300.4	5.0
(6) Consumptive Use	1,890.8	4.1	1,883.1	4.1	1,741.8	3.9	1,833.9	4.0	1,835.4	4.0	1,837.0	4.0
(7) Leaching Requirement @ 0%	224.4	0.5	216.6	0.5	217.4	0.5	226.3	0.5	208.5	0.5	218.6	0.5
(8) Total Beneficial Use	2,115.2	4.6	2,099.7	4.6	1,959.2	4.3	2,060.2	4.5	2,043.9	4.4	2,055.6	4.5
							(In Percent)					
Water Use Efficiencies:												
Conveyance System	85.3	--	85.6	--	85.4	--	86.8	--	85.9	--	85.8	--
On-farm Irrigation	81.4	--	83.5	—	78.2	—	77.2	--	79.0	—	79.9	--
District Irrigation	69.4	—	71.5	—	66.8	--	67.0	--	67.9	—	68.5	—
Unit Irrigation	91.1	--	93.2	--	88.0	—	86.7	--	87.9	--	89.4	—

Water Use Efficiency

The water use efficiencies of the Coachella Valley Water District and the Imperial Irrigation District were derived in earlier sections of this report for various categories including on-farm, District and conveyance. Presented in Table 12 is a summary of those figures for the study period. Comparison of average on-farm and unit irrigation efficiencies indicate a difference of about 15 percent at on-farm level and 16 percent when leaching is included in the calculation (Unit Irrigation Efficiency).

In terms of District and conveyance efficiencies, IID, historically operated more efficiently than Coachella, based on water delivered at Drop No. 1 for both districts. The obvious reason was the high loss rate from the Coachella Canal. This was recognized by CVWD and was partially resolved by replacing the first 49-mile reach with a lined section, accomplished by 1981. The effect of this canal lining is evident from a comparison of the data for 1980 and 1981. They show an increase in conveyance efficiency for CVWD of over 15 percent. Data for IID for the same period indicate no significant change.

Specific differences between CVWD and IID can be used in a qualitative sense to describe reasons for differences in the quantitative evaluation of water use efficiencies.

1. Soils in CVWD are generally coarser and more permeable than those in IID. Therefore, even though on-farm irrigation systems in CVWD use modern technological

Table 12

WATER USE EFFICIENCY OF
COACHELLA VALLEY WATER DISTRICT
AND
IMPERIAL IRRIGATION DISTRICT
(In percent)

Year	On-Farm		Unit		Conveyance		District	
	CVWD	IID	CVWD	IID	CVWD	IID	CVWD	IID
1976	62	81	70	91	69	85	46	69
77	64	84	71	93	68	86	47	72
78	66	78	74	88	67	85	48	67
79	67	77	75	87	63	87	46	67
80	66	79	74	88	65	86	47	68
Avg. 1976-80	65	80	73	89	66	86	47	69

advances (drip systems on about 50 percent of the irrigated land), high rates of percolation make high on-farm irrigation efficiencies difficult to achieve on crops not susceptible to these systems.

2. Conveyance system losses were greater in the CVWD system than in IID. The alignment of the Coachella Canal generally follows the base of the foothills where soils are relatively coarse textured according to the Soil Conservation Service Report. Generally finer (tighter) soils underlie the IID conveyance system. Over the many years of operation, suspended solids in the Colorado River water tend to seal the canal prism and limit seepage therefrom. This tends to offset the fact that most of the CVWD system is concrete-lined canals or pipe.

3. The CVWD service area is further from the water source (Drop No. 1) than that of IID. This additional length contributed to greater total losses relative to total deliveries.

It is again noted that replacing the initial 49 miles of the Coachella Canal has made a significant contribution to the District and conveyance efficiencies of CVWD.

Presented in Table 13 (based on the DWR 1981 Report on the Imperial Irrigation District) is a comparison of on-farm and district irrigation efficiencies for the 1975 through 1978

Table 13

DELIVERY EFFICIENCIES OF IRRIGATION DISTRICTS
(In percent)

	1975	1976	1977	1978
Imperial Irrigation District				
on-farm efficiency	73	80	81	77
district efficiency	65	71	73	70
Coachella Valley W.D.				
on-farm efficiency	51	50	55	53
district efficiency	43	44	46	46
Reservation Div. I.D.				
on-farm efficiency	45	47	58	60
district efficiency	36	38	47	50
Y.C.W.U.A. (Valley Div.) I.D.				
on-farm efficiency	64	80	71	72
district efficiency	49	60	54	52
Yuma Mesa Irrig. & D.D.				
on-farm efficiency	33	33	29	32
district efficiency	30	30	27	30
Unit "B" Irrig. Dist.				
on-farm efficiency	33	32	35	38
district efficiency	32	31	33	36
Yuma Irrigation Dist.				
on-farm efficiency	62	63	61	61
district efficiency	59	61	59	53
North Gila Irrig. Dist.				
on-farm efficiency	29	40	46	42
district efficiency	28	30	43	40
Wellton-Mokhawk Irrig. Dist.				
on-farm efficiency	55	52	63	64
district efficiency	50	47	57	57
Colorado River Indian Tribes				
on-farm efficiency	57	65	76	64
district efficiency	44	50	58	48
Palo Verde Irrig. Dist.				
on-farm efficiency	46	33	45	42
district efficiency	36	26	35	33

* This table is based on Exhibit C from an "Affidavit of Maurice N. Langley..." in Civil Action No. 76-10957 in United States District Court, (no date). Source: U.S. Bureau of Reclamation, unpublished, 1979.

period. Climatic conditions for each of these districts are similar and all use the Colorado River as their supply. Table 14, also from the DWR Report, compares District and conveyance efficiencies for IID and several San Joaquin Valley districts for 1979.

Crop specific irrigation efficiencies were calculated for three San Joaquin Valley areas and presented in Bulletin 160-83 "The California Water Plan, Projected Use and Available Water Supplies to 2010," dated December 1983. Weighted average irrigation efficiencies by crop for 1980 for the three areas are tabulated below:

Examples of Weighted Average Irrigation Efficiencies
by Crop
(In percent)

Crop	Maricopa Wheeler-Ridge 1980	Kern Valley Floor 1980	Tulare Lake 1980
Grain	71	65	70
Cotton	69	68	67
Corn	69	65	58
Other field crops	70	63	64
Alfalfa	70	59	62
Pasture	69	49	51
Tomatoes	70	70	70
Other truck crops	70	70	69
Almonds-pistachios	69	65	66
Other deciduous	71	67	66
Citrus-olive	69	70	67
Grapes	80	70	56

The figures are not necessarily directly comparable to those derived for CVWD and IID but corroborate the order of magnitude.

Table 14

DISTRICT AND CONVEYANCE SYSTEM EFFICIENCIES
CENTRAL VALLEY AND IMPERIAL IRRIGATION DISTRICTS, 1979

District	Delivery System	Irrigation Type	District Efficiency	Conveyance System Efficiency
Westlands W.D.	Closed conduit	70% surface border and furrow 30% sprinkler	70%	98%
Fresno I.D.	Open, unlined canals	80% surface border and furrow 10% sprinklers 10% drip	58%	75%
Corcoran I.D.	Open, unlined canals	100% surface border and furrow	65%	75%
Tulare Lake Basin W.S.D.	Open, lined and unlined canals	100% surface mainly border	70%	90%
Buena Vista W.S.D.	Open, lined and unlined canals	100% surface mainly border	77%	65%
Imperial I.D.	Open, unlined canals	100% surface border and furrow	66%	90%*

Source: Table 11, page 46, DWR, December 1981, "Use of Water by Imperial Irrigation District."

* Average of 1975-79 data.

APPENDIX A

CROP TOLERANCE TABLE

Source: Table 5, Irrigation and Drainage Paper 29, "Water Quality for Agriculture," Food and Agriculture Organization of the United Nations, Rome, 1976.

Table 5

CROP TOLERANCE TABLE

Yield Decrement to be expected for Certain Crops due to Salinity of Irrigation Water when Common Surface Irrigation Methods are Used

Field Crops

CROP	0%		10%		25%		50%		MAXIMUM
	ECe 1/	ECw 2/	ECe	ECw	ECe	ECw	ECe	ECw	ECe 3/
Barley 4/ (Hordeum vulgare)	8.0	5.3	10	6.7	13	8.7	18	12	28
Cotton (Gossypium hirsutum)	7.7	5.1	9.6	6.4	13	8.4	17	12	27
Sugarbeet 5/ (Beta vulgaris)	7.0	4.7	8.7	5.8	11	7.5	15	10	24
Wheat 4/ 6/ (Triticum aestivum)	6.0	4.0	7.4	4.9	9.5	6.4	13	8.7	20
Safflower (Carthamus tinctorius)	5.3	3.5	6.2	4.1	7.6	5.0	9.9	6.6	14.5
Soybean (Glycine max)	5.0	3.3	5.5	3.7	6.2	4.2	7.5	5.0	10
Sorghum (Sorghum bicolor)	4.0	2.7	5.1	3.4	7.2	4.8	11	7.2	18
Groundnut (Arachis hypogaea)	3.2	2.1	3.5	2.4	4.1	2.7	4.9	3.3	6.5
Rice (paddy) (Oryza sativa)	3.0	2.0	3.8	2.6	5.1	3.4	7.2	4.8	11.5
Sesbania (Sesbania macrocarpa)	2.3	1.5	3.7	2.5	5.9	3.9	9.4	6.3	16.5
Corn (Zea mays)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Flax (Linum usitatissimum)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10

Table 5 continued

CROP	0% ECe	0% ECw	10% ECe	10% ECw	25% ECe	25% ECw	50% ECe	50% ECw	MAXIMUM ECe
Broadbean (Vicia faba)	1.6	1.1	2.6	1.8	4.2	2.0	6.8	4.5	12
Cowpea (Vigna sinensis)	1.3	0.9	2.0	1.3	3.1	2.1	4.9	3.2	8.5
Beans (Phaseolus vulgaris)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.5
Fruit Crops									
Date palm (Phoenix dactylifera)	4.0	2.7	6.8	4.5	10.9	7.3	17.9	12	32
Fig (Ficus carica) Olive (Olea europaea) Pomegranate (Punica granatum)	2.7	1.8	3.8	2.6	5.5	3.7	8.4	5.6	14
Grapefruit (Citrus paradisi)	1.8	1.2	2.4	1.6	3.4	2.2	4.9	3.3	8
Orange (Citrus sinensis)	1.7	1.1	2.3	1.6	3.2	2.2	4.8	3.2	8
Lemon (Citrus limonea)	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8
Apple (Pyrus malus) Pear (Pyrus communis)	1.7	1.0	2.3	1.6	3.3	2.2	4.8	3.2	8
Walnut (Juglans regia)	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8
Peach (Prunus persica)	1.7	1.1	2.2	1.4	2.9	1.9	4.1	2.7	6.5
Apricot (Pyrus armeniaca)	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	6
Grape (Vitis spp.)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12

Ta. 5 continued

CROP	0%		10%		25%		50%		MAXIMUM
	ECe	ECw	ECe	ECw	ECe	ECw	ECe	ECw	ECe
Almond (Prunus amygdalus)	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.7	7
Plum (Prunus domestica)	1.5	1.0	2.1	1.4	2.9	1.9	4.3	2.8	7
Blackberry (Rubus spp.)	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6
Boysenberry (Rubus spp.)	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6
Avocado (Persea americana)	1.3	0.9	1.8	1.2	2.5	1.7	3.7	2.4	6
Raspberry (Rubus idaeus)	1.0	0.7	1.4	1.0	2.1	1.4	3.2	2.1	5.5
Strawberry (Fragaria spp.)	1.0	0.7	1.3	0.9	1.8	1.2	2.5	1.7	4
Vegetable Crops									
Beets 5/ (Beta vulgaris)	4.0	2.7	5.1	3.4	6.8	4.5	9.6	6.4	15
→ Broccoli (Brassica italica)	2.8	1.9	3.9	2.6	5.5	3.7	8.2	5.5	13.5
Tomato (Lycopersicon esculentum)	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	12.5
Cucumber (Cucumis sativus)	2.5	1.7	3.3	2.2	4.4	2.9	6.3	4.2	10
Cantaloupe (Cucumis melo)	2.2	1.5	3.6	2.4	5.7	3.8	9.1	6.1	16
Spinach (Spinacia oleracea)	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7	15
Cabbage (Brassica oleracea capitata)	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12

Table 5 continued

CROP	0% ECe	0% ECw	10% ECe	10% ECw	25% ECe	25% ECw	50% ECe	50% ECw	MAXIMUM ECe
Potato (Solanum tuberosum)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Sweet corn (Zea mays)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Sweet potato (Ipomea batatas)	1.5	1.0	2.4	1.6	3.8	2.5	6.0	4.0	10.5
Pepper (Capsicum frutescens)	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	8.5
Lettuce (Lactuca sativa)	1.3	0.9	2.1	1.4	3.2	2.1	5.2	3.4	9
Radish (Raphanus sativas)	1.2	0.8	2.0	1.3	3.1	2.1	5.0	3.4	9
Onion (Allium cepa)	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.5
Carrot (Daucus carota)	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.1	8
Beans (Phaseolus vulgaris)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.5
Forage Crops									
Tall wheat grass (Agropyron elongatum)	7.5	5.0	9.9	6.6	13.3	9.0	19.4	13	31.5
Wheat grass (fairway) (Agropyron elongatum)	7.5	5.0	9.0	6.0	11	7.4	15	9.8	22
Bermuda grass 7/ (Cynodon dactylon)	6.9	4.6	8.5	5.7	10.8	7.2	14.7	9.8	22.5
Barley (hay) 4/ (Hordeum vulgare)	6.0	4.0	7.4	4.9	9.5	6.3	13.0	8.7	20

Table 5 continued

CROP	0% ECe	0% ECw	10% ECe	10% ECw	25% ECe	25% ECw	50% ECe	50% ECw	MAXIMUM ECe
Perennial rye grass (Lolium perenne)	5.6	3.7	6.9	4.6	8.9	5.9	12.2	8.1	19
Trefoil, birdsfoot narrow leaf[9/] (L. corniculatus tenuifolius)	5.0	3.3	6.0	4.0	7.5	5.0	10	6.7	15
Harding grass (Phalaris tuberosa)	4.6	3.1	5.9	3.9	7.9	5.3	11.1	7.4	18
Tall fescue (Festuca elatior)	3.9	2.6	5.8	3.9	8.6	5.7	13.3	8.9	23
Crested Wheat grass (Agropyron desertorum)	3.5	2.3	6.0	4.0	9.8	6.5	16	11	28.5
Vetch (Vicia sativa)	3.0	2.0	3.9	2.6	5.3	3.5	7.6	5.0	12
Sudan grass (Sorghum sudanense)	2.8	1.9	5.1	3.4	8.6	5.7	14.4	9.6	26
Wildrye, beardless (Elymus triticoides)	2.7	1.8	4.4	2.9	6.9	4.6	11.0	7.4	19.5
Trefoil, big (Lotus uliginosis)	2.3	1.5	2.8	1.9	3.6	2.4	4.9	3.3	7.5
Alfalfa (Medicago sativa)	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	15.5
Lovegrass[8/] (Eragrostis spp.)	2.0	1.3	3.2	2.1	5.0	3.3	8.0	5.3	14
Corn (forage) (Zea mays)	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15.5
Clover, berseem (Trifolium alexandrinum)	1.5	1.0	3.2	2.1	5.9	3.9	10.3	6.8	19
Orchard grass (Dactylis glomerata)	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	17.5

Table 5 continued

CROP	0%		10%		25%		50%		MAXIMUM
	ECe	ECw	ECe	ECw	ECe	ECw	ECe	ECw	ECe
Meadow foxtail (Alopecurus pratensis)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12
Clover, alsike, ladino, red, strawberry (Trifolium spp.)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	10

FOOTNOTES

1/ ECe means electrical conductivity of the saturation extract of the soil reported in millimhos per centimetre at 25°C.

2/ ECw means electrical conductivity of the irrigation water in millimhos per centimetre at 25°C. This assumes about a 15-20% leaching fraction and an average salinity of soil water taken up by crop about three times that of the irrigation water applied (ECsw = 3 ECw) and about two times that of the soil saturation extract (ECsw =2ECe). From the above, ECe = 3/2 ECw. New crop tolerance tables for ECw can be prepared for conditions which differ greatly from those assumed in the GUIDELINES. The following are estimated relationships between ECe and ECw for various leaching fractions: LF = 10% (ECe = 2 ECw), LF = 30% (ECe = 1.1 ECw), and LF = 40% (ECe = .9 ECw). [See figure 2 and Appendix C.]

3/ Maximum ECe means the maximum electrical conductivity of the soil saturation extract that can develop due to the listed crop withdrawing soil water to meet its evapotranspiration demand. At this salinity, crop growth ceases (100% yield decrement) due to the osmotic effect and reduction in crop water availability to zero (see Fig. 5).

4/ Barley and wheat are less tolerant during germination and seedling stage. ECe should not exceed 4 or 5 mmhos/cm

5/ Sensitive during germination. ECe should not exceed 3 mmhos/cm for garden beets and sugar beets.

6/ Tolerance data may not apply to new semi-dwarf varieties of wheat.

7/ An average for Bermuda grass varieties. Suwannee and Coastal are about 20% more tolerant; Common and Greenfield are about 20% less tolerant.

8/ Average for Boer, Wilman, Sand, and Weeping varieties. Lehman appears about 50% more tolerant.

9/ Brood-leaf birdsfoot trefoil appears to be less tolerant than narrow-leaf.

Source: Data as reported by Maas and Hoffman (in press); Bernstein (1964), and University of California Committee of Consultants (1974).

12-14

COACHELLA VALLEY WATER PROBLEM:

SEVERE GROUNDWATER OVERDRAFT

"POSSIBLE STRATEGIES AND OPPORTUNITIES"

1997

COACHELLA VALLEY WATER DISTRICT

COACHELLA VALLEY WATER DISTRICT
P.O. BOX 1058
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Table of Contents

SECTION 1
INTRODUCTION AND SUMMARY

The Coachella Valley Water District (District), located in Southern California, was formed in 1918 under the California Water Code provisions of the County Water District Act.

A governing Board of Directors with five members representing individual divisions are elected to four-year terms.

Nearly 640,000 acres are within the District boundaries, mostly in Riverside County but the District also extends into San Diego and Imperial counties.

The District provides six water service categories:

- irrigation water,
- domestic water,
- stormwater protection,
- agricultural drainage,
- wastewater reclamation and reuse, and
- water conservation.

Recreation and the generation of energy are incidental benefits of some of the water service activities

WATER PROBLEM
SEVERE GROUNDWATER OVERDRAFT

When the District was formed in 1918 the groundwater table was dropping. Farmers were using more water and artesian wells had ceased flowing. The District signed its first contract with the federal government for Colorado River water supplies in 1919. Water levels continued to drop (in the lower valley wells were 40 to 50 feet lower) until Colorado River deliveries began in 1949. When farmers converted from wells to Colorado River water supplies, the water level recovered within 15 years (1965).

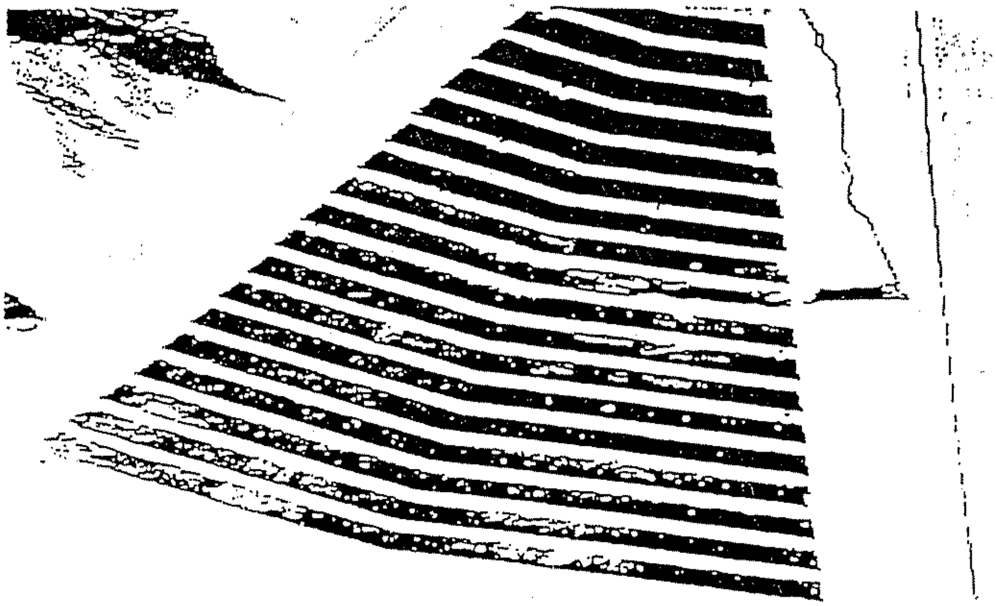
However, water demands increased in the 1980s to such an extent that water levels have dropped to their lowest level. As a result, the District has begun preparation of a *Water Management Plan* to eliminate the groundwater overdraft. Sophisticated groundwater modeling and analysis is currently under way to determine the best groundwater management strategies.

STRATEGIES AND OPPORTUNITIES

- Implementation of water conservation measures (best management practices, BMPs) for urban water use, including "state-of-the-art" outdoor irrigation technology (CIMIS) for golf courses and other large landscape areas.

- Use recycled water through canal water delivery system to avoid capital cost of constructing new pipeline distribution systems

- Use wet year "surplus" State Water Project supplies to recharge Upper Valley aquifers
- Increased use of recycled water throughout the Coachella Valley for golf course, agricultural and other non-potable uses.
- Internal recycling of fish farm effluent water and distribution of fish farm effluent for agricultural use.
- Implement Colorado River Banking Concept: store surplus Colorado River water through direct replenishment (spreading basins) and in-lieu replenishment (build Oasis and other irrigation delivery systems) to alleviate Lower Coachella Valley groundwater overdraft.
- Expand irrigation delivery system to serve all farmers



Upper Valley Banking Concept

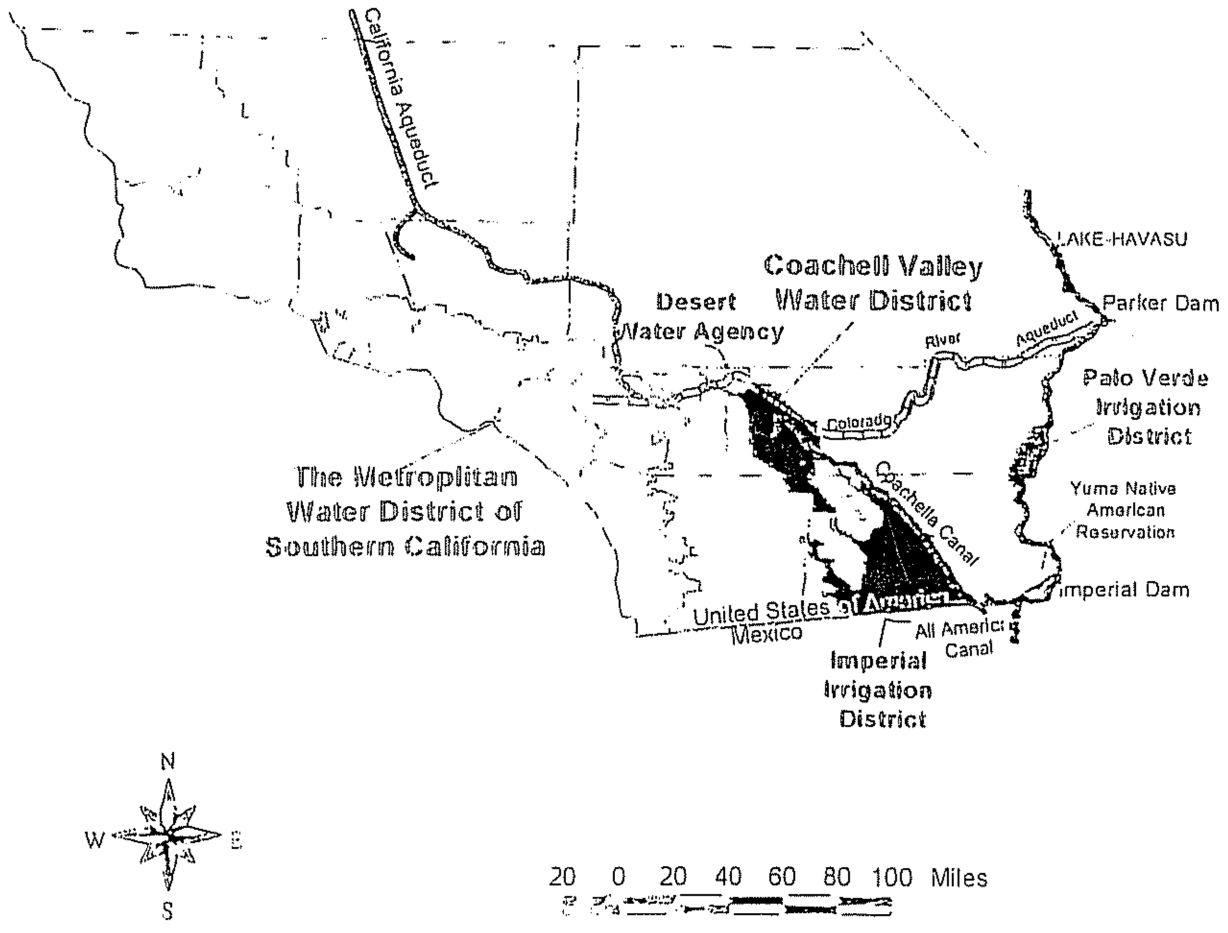
Expand Whitewater spreading operation with State Water Project surplus supplies and water transfers from northern California. Exchange supplies with Metropolitan Water District for Colorado River Aqueduct deliveries.

Lower Valley Banking Concept

Banking Colorado River water is the critical strategy to reducing the severe overdraft of the Lower Coachella Valley. In addition, implement conservation BMPs, expand the use of recycled water and capture storm water for recharge of the groundwater basin

Figure 1

WATER DISTRICTS IN SOUTHERN CALIFORNIA



SECTION 2
HISTORY AND CURRENT WATER ISSUES

COACHELLA VALLEY WATER DISTRICT CHRONOLOGICAL HISTORY

1918 The District is formed.
1928 Boulder Canyon Project Act signed into law (authorizes Hoover Dam and All-American Canal).
1934 Coachella Canal construction starts, however, stops during World War II and resumes in 1944.
1947 Coachella Valley residents vote to approve $13.5 million repayment contract with Bureau of Reclamation.
1949 Initial deliveries of Colorado River water to Coachella Valley.
1963 District executes contract with California Department of Water Resources for State Water Project (SWP) supplies (23,100 acre-feet).
1973 The District begins receiving Colorado River water at the Whitewater spreading grounds from The Metropolitan Water District of Southern California (MWD) in exchange for the District's SWP supplies.
1981 MWD pre-delivery banking agreement of 600,000 acre-feet executed.
1988 The All American Canal Legislation is passed by Congress and signed into law.
1995 Bureau of Reclamation and District execute Memorandum of Understanding.
1996 The District satisfies all the requirements for RRA and was exempted from further reporting requirements.

CURRENT WATER SUPPLIES AND DEMAND

The Coachella Valley has two primary sources of supply, local groundwater, and imported water from the Colorado River (SWP supplies are exchanged with MWD). Local stormwater is captured and conserved through the Whitewater River recharge facilities. Recycling treated wastewater has increased the efficiency of imported water by reuse. Since the local groundwater supplies are being severely overdrafted the only opportunity to develop new supplies is from the delivery of additional Colorado River water through the Coachella Canal and increases in SWP supplies exchanged with MWD.

KEY POINT

DEMAND IS PROJECTED TO INCREASE

Upper Valley:
1995 188,000 acre-feet per year
2015 250,000 acre-feet per year

Lower Valley:
1995 475,000 acre-feet per year
2015 550,000 acre-feet per year

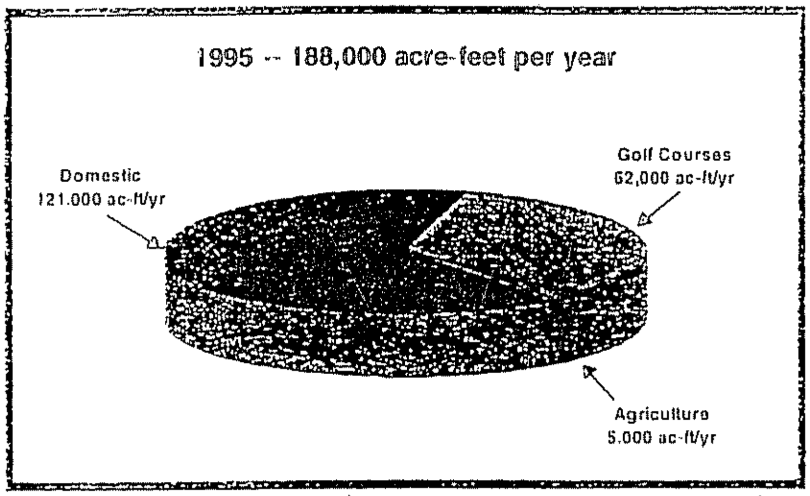
This new demand is about 137,000 acre-feet per year.

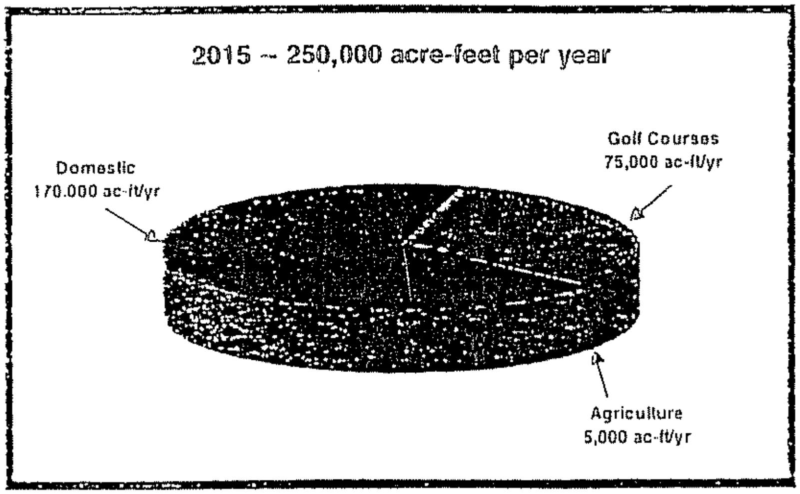
CURRENT AND FUTURE TRENDS

The Coachella Valley lies east and south of the San Jacinto and San Bernardino mountains, which rise to over 10,000 feet above sea level. The principal river drainage is the Whitewater River from the San Bernardino Mountains to its discharge into the Salton Sea (see map on Figure 2). The valley's groundwater basin is divided into an Upper and Lower area (see boundary of Upper and Lower basins.)

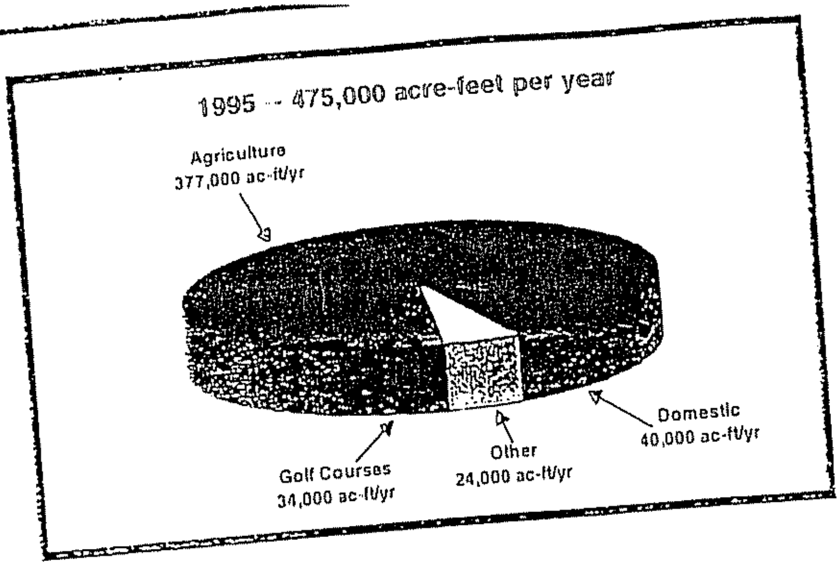
Upper Valley

The upper valley is characterized primarily by domestic usage. This is due to the large number of resort communities located in this area. Similarly, golf course demands are high in the upper valley. A very small portion of the upper valley is used for agricultural purposes. The demands on the water supply in the upper valley are shown for the years 1995 and 2015.

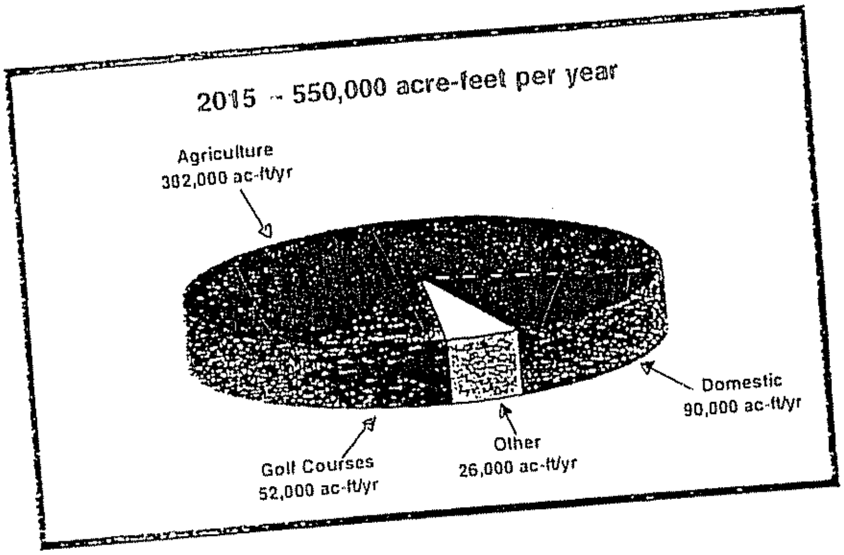




Lower Valley

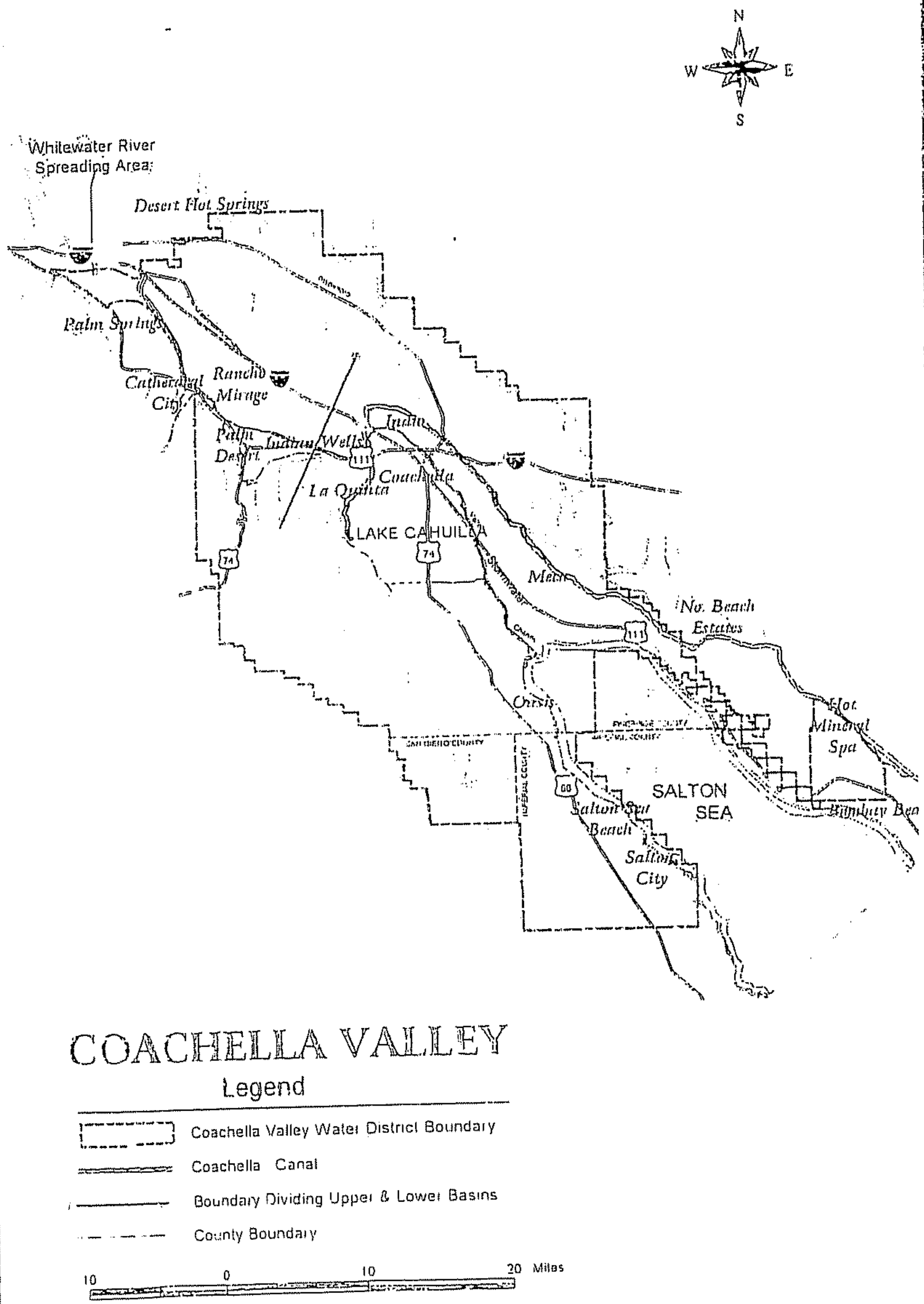


The water demand in the Lower Valley is primarily for agricultural use. Other water demands in the Lower Valley include domestic, golf courses, and other uses such as fish farms, duck clubs, greenhouses and industrial facilities. The Lower Valley demand is projected to increase to about 550,000 acre-feet (an increase of approximately 15 percent) by the year 2015



Total demands for the Coachella Valley are 662,500 acre-feet per year in 1995 and 800,000 acre-feet per year in 2015 and represent the sums of the Upper and Lower valley demands.

Figure 2


N
W
E
S
Whitewater River
Spreading Area
Desert Hot Springs
Palm Springs
Rancho
Mirage
Cathedral
City
Palm
Desert
Indian Wells
Indio
Coachella
La Quinta
LAKE CAHUILLA
Mecca
No. Beach
Estates
Oasis
Hot
Mineral
Spa
SALTON
SEA
Salton Sea
Beach
Salton
City
COACHELLA VALLEY
Legend
Coachella Valley Water District Boundary
Coachella Canal
Boundary Dividing Upper & Lower Basins
County Boundary
10
0
10
20 Miles

SECTION 3
IMPACTS OF OVERDRAFT

Groundwater extraction in significant or sustained excess of long-term groundwater supply, overdraft, can result in a number of deleterious impacts to the Coachella Valley. These include ground surface subsidence, aquifer and aquitard compaction, earth fissures, increasing pump lifts and intrusion of Salton Sea waters into the groundwater basin.

Surface Subsidence. In areas similar to the Lower Coachella Valley where aquifers and aquitards consist of unconsolidated to semi-consolidated alluvial materials in a partially confined (pressure) condition, subsidence of the land surface is likely to occur as aquifer pressure levels are reduced by sustained overdraft conditions. The reduction in artesian pressure results in an increased load on the soil column which may cause compaction of the sediments. This compaction is clearly dependent upon both the subsurface rock formations and the duration and magnitude of pressure decline. Subsidence may extend to depths of 1,000 feet. In general terms, once the compaction and subsidence have occurred, the change is essentially permanent and no rebound results when pressure levels are restored. Clearly, damages from subsidence can include major problems with drainage and irrigation systems.

Groundwater levels in some locations in the Lower Valley have declined about 40 to 70 feet from 1980 to 1993. Based on District data, groundwater levels in the Lower Coachella Basin appear to have been declining at an average rate of approximately 4.8 feet per year during this period. Groundwater levels in the Upper Valley have declined only about 15 feet. As water levels have declined in the Lower Aquifer, the saturated cross-sectional area for inflow from the Upper Valley has similarly declined. This has resulted in reduced subsurface inflow to the Lower Valley. Currently, recharge to the Upper Valley is derived largely from the Whitewater River spreading facility.

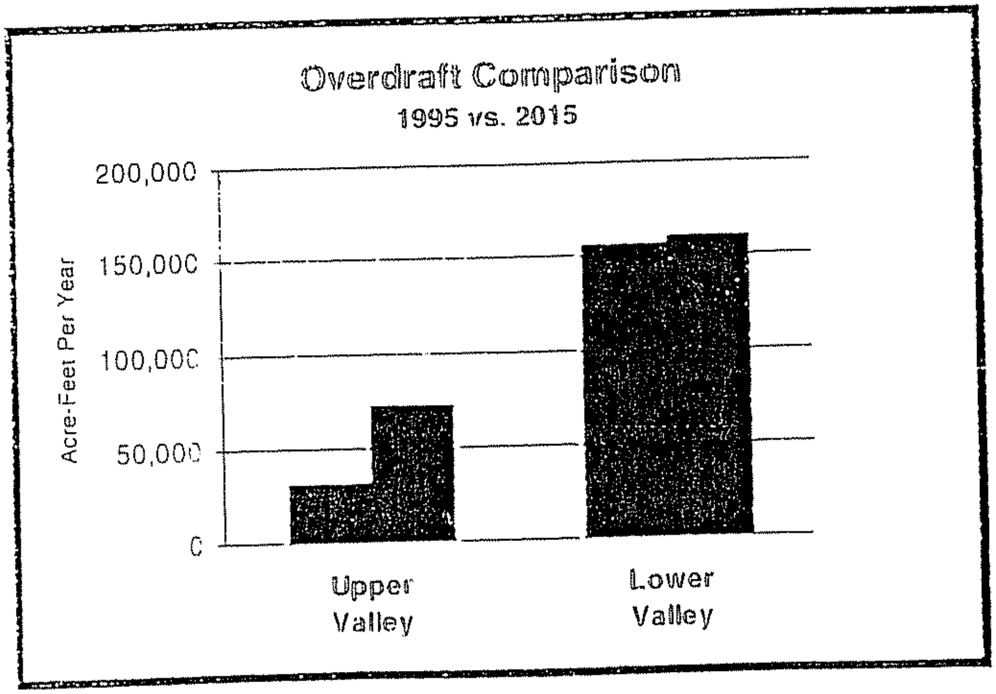
REDUCING THE GROUNDWATER OVERDRAFT

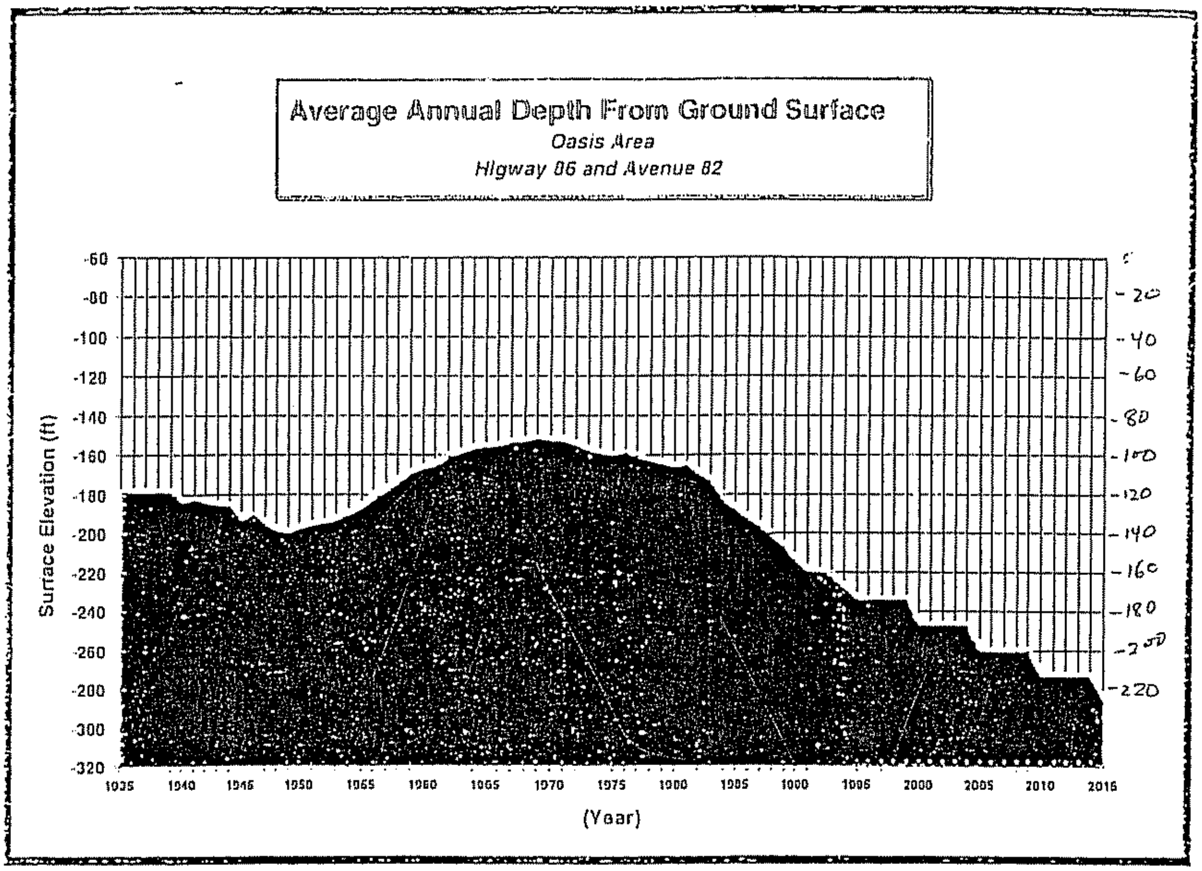
WATER MANAGEMENT PROBLEM

Historically this trend was reduced through the importation of Colorado River water in the late 1940s via the Coachella Canal. Previously, water tables were dropping when the District was formed in 1918. Water levels dropped from 1918 until the 1940s in the range of 40 to 50 feet. In 1949 farmers began converting from wells to Colorado River water supplies. Groundwater levels then began to rise and reached their 1918 levels within 15 years. In the 1960s and 1970s levels remained relatively stable until new demands and increased groundwater pumping has again caused water levels to decline. During the last 15 years groundwater levels have declined approximately 40 to 70 feet in the lower valley.

1995 COACHELLA VALLEY GROUNDWATER BASIN WATER BALANCE AND OVERDRAFT

Component	Upper Valley (af/yr) 1995	Upper Valley (af/yr) (2015)	Lower Valley (af/yr) 1995	Lower Valley (af/yr) (2015)	Total (af/yr) 1995	Total (af/yr) (2015)
INFLOW						
Surface Inflow						
Natural Recharge	34,000	(34,000)	4,000	(4,000)	38,000	(38,000)
Artificial Recharge						
Canal Water	0	0	0	0	0	0
State Water Project	53,000	(53,000)	0	0	53,000	(53,000)
Return Flows	60,000	(67,000)	21,000	(22,000)	81,000	(89,000)
Subsurface Flows	11,000	(11,000)	15,000	(15,000)	26,000	(26,000)
Total Inflow	**158,000**	**(165,000)**	**40,000**	**(41,000)**	**198,000**	**(206,000)**
OUTFLOW						
Groundwater extraction	176,300	(224,400)	181,300	(186,600)	357,600	(411,000)
Subsurface to Lower Valley	14,000	(14,000)	0	0	14,000	(14,000)
Subsurface to Salton Sea	0		15,000	(15,000)	15,000	(15,000)
Total Outflow	**190,300**	**(238,400)**	**196,300**	**(201,600)**	**386,600**	**(440,000)**
Water Supply Deficiency (overdraft)	32,300	(73,400)	156,300	(160,600)	188,600	(234,000)




Average Annual Depth From Ground Surface
Oasis Area
Higway 86 and Avenue 82
Surface Elevation (ft)
(Year)

SECTION 4
POTENTIAL GROUNDWATER STORAGE PROGRAMS

BACKGROUND

- The Coachella Valley is split into an Upper and Lower Valley
- Groundwater is a major source of supply.
- The Upper Valley is primarily supplied by groundwater with a significant portion being artificially recharged through spreading in the Whitewater River with SWP entitlement exchanged with Colorado River supplies from MWD.
- The Lower Valley is mostly supplied by canal water (about 300,000 acre-feet per year), but the use of groundwater is also significant (185,000 acre-feet per year).
- The Lower Valley has significant limitations for recharging the groundwater basin due to a clay layer.
- Most of the demand for groundwater in the Upper Valley is for domestic purposes and golf courses. No canal water is used in the Upper Valley.
- Most of the demand for groundwater in the Lower Valley is for agricultural use, but uses for domestic purposes, golf courses, fish farms, and industry are also significant. Agricultural users in the Lower Valley mainly use canal water.
- SWP entitlements are 23,100 acre-feet per year for Coachella and 38,100 acre-feet per year for Desert Water Agency (total 61,200 acre-feet per year).

COACHELLA WATER SUPPLY
(acre-feet per year)

Sources of Supply	Upper Valley 1995	Upper Valley 2015	Lower Valley 1995	Lower Valley 2015	Total 1995	Total 2015
Canal Water (CR)	0	0	300,000	342,600	300,000	500,000
Surface Water	5,800	5,800	0	0	5,800	5,800
Reclaimed Water	6,000	21,200	0	0	6,000	21,200
Groundwater	176,300	224,400	181,300	186,600	357,600	411,000
TOTAL	**188,100**	**251,400**	**481,300**	**529,200**	**669,400**	**938,000**

Coachella's Groundwater Overdraft Problem

- The natural recharge (from surface runoff) is about 34,000 acre-feet per year for the Upper Valley and 4,000 acre-feet per year for the Lower Valley.

- The Desert Water Agency/Coachella advanced exchange program with MWD using Whitewater River Spreading Facility in the Upper Valley accounts for 50,000 to 60,000 acre-feet per year of recharge in exchange for Desert and Coachella's SWP entitlement (61,200 acre-feet, combined).

- At this time, there is no artificial recharge using canal water in the Lower Valley. Pilot facilities are being tested and show promise. Maybe as much as 30,000 to 40,000 acre-feet per year can be artificially recharged in the Lower Valley.

- Return flows (unused supplies from domestic and agricultural irrigation) are another source of groundwater supply. Return flows are 60,000 acre-feet per year for the Upper Valley and 21,000 acre-feet per year for the Lower Valley.

- Subsurface inflow to the Upper Valley is currently 11,000 acre-feet per year. Subsurface inflow to the Lower Valley is currently 15,000 acre-feet per year.

- Based on the amounts of total groundwater inflow and outflow (production and subsurface losses), there is a current overdraft in the Upper Valley of about 32,000 acre-feet per year. By 2015, the overdraft will be 73,000 acre-feet per year

- The current groundwater overdraft in the Lower Valley is 156,000 acre-feet per year. By 2015, the overdraft is projected to increase to 161,000 acre-feet per year.

Potential Strategies for Groundwater Overdraft

- Coachella's Groundwater Management Program objectives are to:

  (1) eliminate overdraft;
  (2) return the groundwater table to mid-1970s levels;
  (3) preserve economic strength of Lower Valley;
  (4) accommodate development in the Lower Valley; and
  (5) preserve beneficial use of the groundwater basin

- Some of the strategies identified by Coachella to reduce the groundwater overdraft include:

  (1) demand reductions through conservation;
  (2) use of additional canal water (Colorado River);
  (3) wastewater reuse and recycling;
  (4) artificial groundwater recharge, and
  (5) water transfers from the San Joaquin Valley and surplus SWP deliveries (Upper Valley via Whitewater)

SECTION 5
UPPER VALLEY OPPORTUNITIES

UPPER VALLEY GROUNDWATER STORAGE PROGRAM

- In 1972 the District constructed the initial nine percolation ponds to allow imported water (Colorado River) to be spread into the Whitewater Riverbed.

- Desert Water Agency and the District exchange their SWP entitlement for MWD's Colorado River water.

- An Advance Delivery Agreement which allows MWD to deliver Colorado River water in advance to be stored in the Upper Valley groundwater basin. Currently about 350,000 acre-feet is in this storage account.

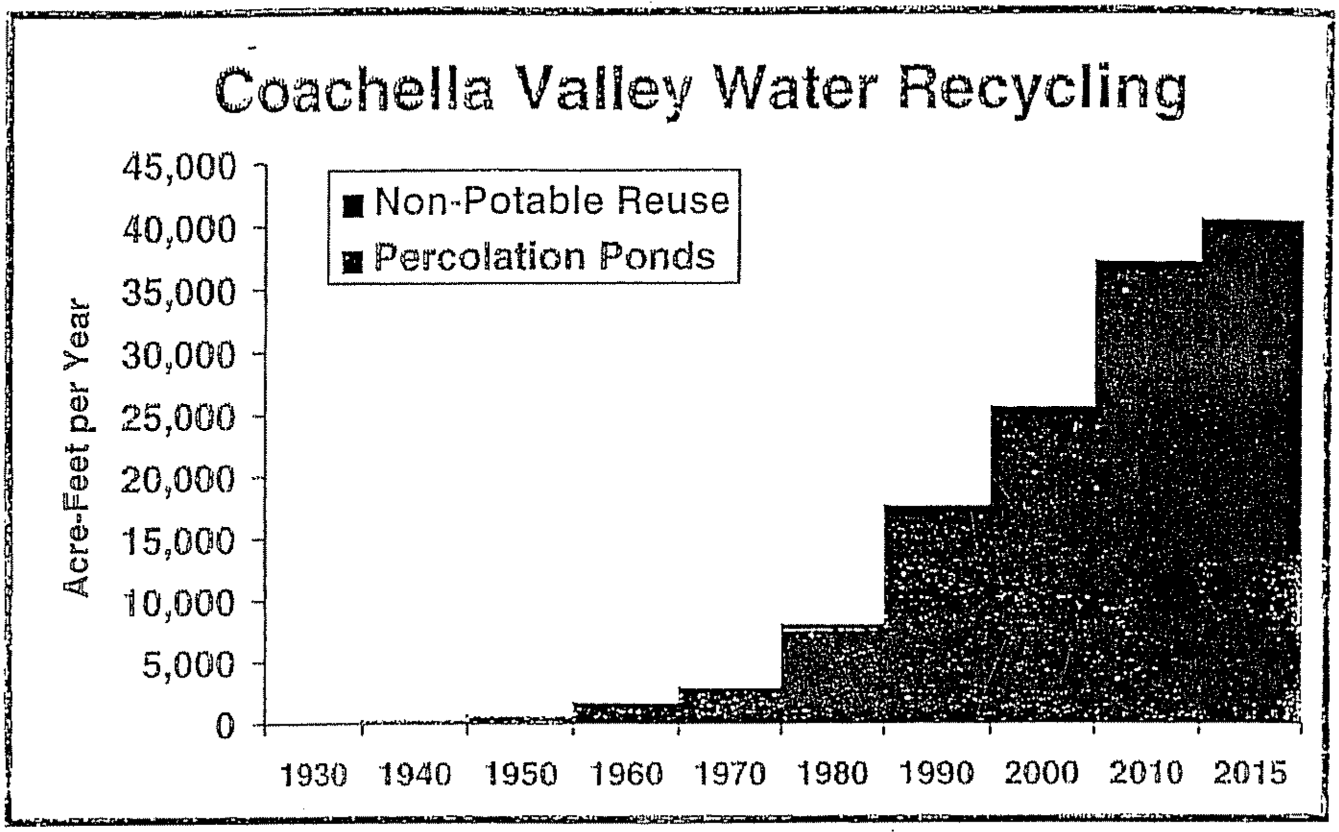
- As necessary, MWD can suspend deliveries of up to 61,200 acre-feet of exchange water to Desert Water Agency and the District in a year and continue to receive delivery of these agencies' SWP water.

- In 1996, over 100,000 acre-feet of surplus SWP supplies were delivered to Whitewater under the MWD exchange agreement. During 1997, an additional 62,000 acre-feet of surplus SWP supplies will be exchanged with MWD.

WATER RECYCLING AND CONSERVATION PROGRAMS

- The District has implemented "state-of-the-art" water conservation programs and is committed to continuing to implement aggressive water conservation programs to ensure efficient water use practices.

- The District has plans to maximize the use of recycled water for groundwater replenishment and for non-potable irrigation uses. Current recycled water use is about 15,000 acre-feet per year in the Upper Valley and is projected to increase to about 40,000 acre-feet per year (2015).


Coachella Valley Water Recycling
Non-Potable Reuse
Percolation Ponds
Acre-Feet per Year
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1930 1940 1950 1960 1970 1980 1990 2000 2010 2015

SECTION 6
LOWER VALLEY OPPORTUNITIES

LOWER VALLEY COLORADO RIVER BANKING CONCEPT

Currently the District imports on average about 350,000 acre-feet annually from the Colorado River. Banking Colorado River supplies in the Lower Valley is the key strategy to reducing the severe overdraft situation. The concept is to recharge Colorado River supplies delivered through the Coachella Canal via spreading grounds and providing surface delivery to farmers as an alternative supply to pumping groundwater ("in-lieu" replenishment). When abundant Colorado River supplies are available, the District would recharge about 150,000 acre-feet.

District Normal Demand	350,000 af/yr
District Banking	150,000 af/yr
Total Colorado River Delivery	500,000 af/yr

In years when Colorado River supplies are restricted, the District would reduce its delivery of Colorado River supplies below its normal supply of 350,000 acre-feet. This would provide a conjunctive use operation to the benefit of other California users of the Colorado River.

OASIS AREA DELIVERY SYSTEM DEMONSTRATION PROJECT

The Oasis area consists of approximately 9,200 acres of extremely productive farmland in the southwest portion of the Coachella Valley. The area currently does not have access to irrigation water from the Coachella Canal and is dependent on groundwater for its irrigation needs. Annual irrigation demands for the area total about 42,000 acre-feet per year. Of the 9,200 total acres, 6,700 acres with an annual demand of 30,000 acre-feet are within the District's irrigation district and currently eligible to receive canal water under the District's contract with the Bureau of Reclamation.

The project as proposed would consist of several components.

- A surface delivery system to provide Coachella Canal water to those portions of the area eligible to receive canal water;
- A surface delivery system to provide surplus Colorado River water to those portions of the Oasis area not eligible to receive Coachella Canal water under the District's contract with the Bureau of Reclamation;
- Spreading facilities to allow effective replenishment of local groundwater supplies; and
- A recycled water pipeline and pumping facility to allow reuse of high quality aquaculture effluent that is currently being wasted to the Salton Sea.

Surface delivery system to eligible portions of the Oasis area. This system would consist of a piping network which would enable the eligible lands within the Oasis area to receive Coachella Canal water as their primary source of irrigation water. There are approximately 6,700 acres of eligible land with an estimated annual demand of 30,000 acre-feet. This component of the system would represent a 16 percent reduction of the valley's current overdraft.

Surface delivery system to those portions of the Oasis area not eligible to receive Coachella Canal water. This system would also consist of a piping network capable of providing surplus Colorado River water to these lands as a secondary source of irrigation water. Colorado River water would only be delivered when and if a surplus was declared on the Colorado River. There are approximately 2,500 acres with an estimated annual demand of 12,000 acre-feet. If surplus water was available, use of Colorado River water in lieu of groundwater would represent a 6.5 percent reduction of the current overdraft.

Spreading Facility. The District is currently operating a pilot groundwater recharge facility in this area. Preliminary estimates indicate that a permanent facility capable of recharging 30,000 to 60,000 acre-feet per year is feasible. This use is currently authorized under our contract with the Bureau of Reclamation. Assuming an average recharge of 30,000 acre-feet this component would also result in a 16 percent reduction in the current overdraft.

Reuse system. This component would consist of a pipeline and pumping facility to pump high quality aquacultural effluent back into the irrigation system where it can be put to beneficial use. Currently, approximately 20,000 acre-feet of this high quality water is wasted to the Salton Sea. This component would have the dual benefit of reusing the effluent and additionally substantially reducing the Coachella Valley's flows into the Salton Sea. Reuse of this water would result in an approximate 20 percent reduction in valley flows into the sea and a 11 percent reduction in the current overdraft.

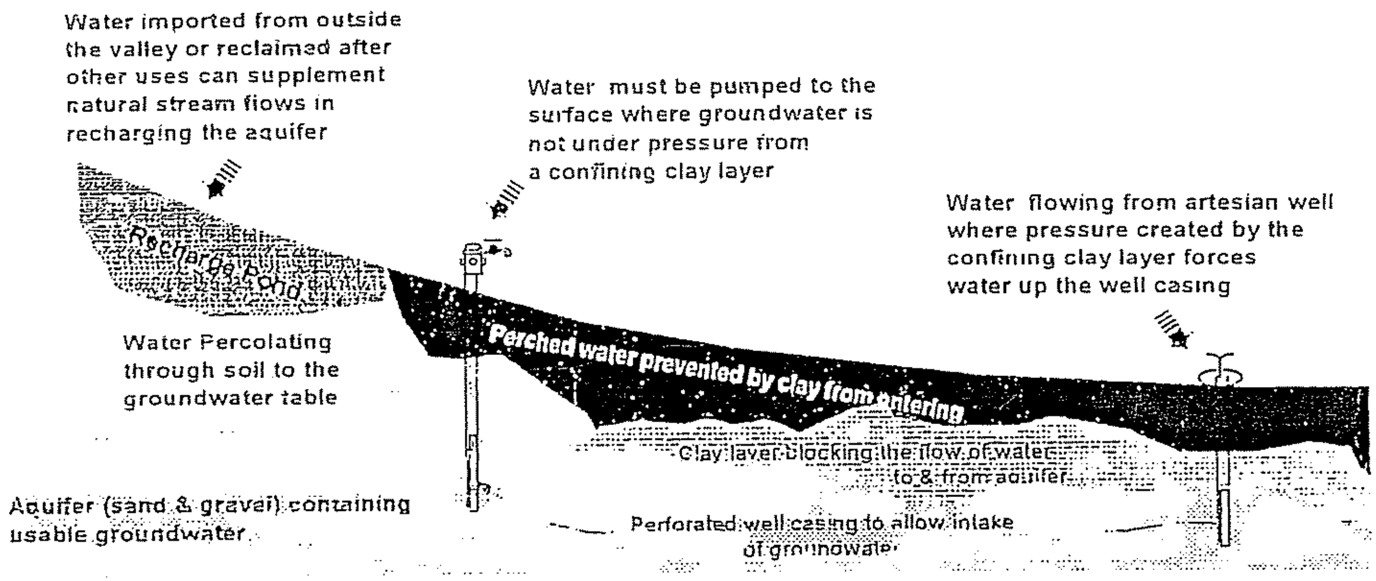
	Estimated Project Costs	Recharge Potential (af/yr)
Oasis irrigation delivery system (eligible)	$15,000,000	30.000
Oasis irrigation delivery system (surplus)	6,000,000	12.000
Oasis spreading facilities	10,000,000	30,000-60,000
Aquaculture recycling/distribution system	2,000,000	20.000
TOTAL	**$33,000,000**	**92,000-122,000**

If fully implemented, the Oasis Area Delivery System Demonstration Project would reduce the current valley-wide overdraft between 40 and 50 percent depending on the availability of surplus Colorado River water

The Oasis area banking project would allow for the delivery of Colorado River supplies in lieu of groundwater pumping and the percolation through spreading basins (like the very successful Whitewater spreading facilities) to recharge up to 30,000 to 60,000 acre-feet per year. When shortages on the Colorado River required the District to reduce delivery of Colorado River supplies, the District would switch these agricultural users back to their existing wells and pump their normal use of 42,000 acre-feet. This conjunctive operation would reduce the lower Valley overdraft significantly and provide flexibility to the Colorado River deliveries to the District. This would benefit the other lower bank Colorado River users

Figure 4

GROUNDWATER BASIN SCHEMATIC



SECTION 7
COLORADO RIVER

The Colorado River Basin is divided into upper and lower regions. California, Arizona, and Nevada form the lower basin states

These lower basin states must be satisfied with 7.5 million acre-feet of Colorado River water annually under the terms of the Colorado River Compact adopted in 1922. Of this, California will be limited to 4 4 million acre-feet when the Central Arizona Project begins full operation. California has used as much as 5.3 million acre-feet in past years

Major Colorado River water users in California are the Coachella Valley Water District, Palo Verde Irrigation District, Imperial Irrigation District, MWD, and Yuma Project (Reservation Division)

Nine major reservoirs with a total gross capacity of 65 million acre-feet serve as storage for the Colorado River and its tributaries in the seven basin states. These are Fontenelle Reservoir on the Green River in Wyoming; Flaming Gorge on the Green River in Wyoming and Utah; the twin reservoirs of Blue Mesa and Morrow Point on the Gunnison River in Colorado, Lake Powell on the Colorado River in Utah and Arizona, Lake Navajo on the San Juan River in New Mexico; Lake Mead on the Colorado River in Arizona and Nevada, Lake Mojave on the Colorado River in Arizona and Nevada; and Lake Havasu on the Colorado River in Arizona and California.

In 1931 the U.S. Secretary of Interior asked that California parties using Colorado River water draw up a priority agreement. Since agricultural users had been the first users they were given first priorities to the water.

The Agreement became known as the Seven Party Water Agreement because of the participants:

- Palo Verde Irrigation District,
- Imperial Irrigation District (IID),
- Coachella Valley Water District,
- The Metropolitan Water District of Southern California (MWD),
- City of San Diego,
- City of Los Angeles, and
- The County of San Diego.

The specified priorities are shown in the table.

COLORADO RIVER DISTRIBUTION

The Coachella branch of the All American Canal was obtained through participation of the District in the Boulder Canyon Project Act adopted by Congress. The contract for construction was signed in 1934.

It was financed by a $23.5 million interest-free loan from the Bureau of Reclamation. The loan is being repaid over a 40-year period

Construction, interrupted by World War II, resumed near the end of the war and was completed in 1948. First water was delivered in March 1949.

Water travels 159 miles from the Imperial Dam, 18 miles north of Yuma, to Lake Cahuilla, terminal reservoir on the Coachella Canal. The Coachella Canal is 122 miles long and branches out from the main All-American 37 miles downstream from the Imperial Dam.

The canal terminates near Avenue 57 on the west side of the Coachella Valley. It has a capacity of 1,300 cubic feet per second or 2,578 acre-feet in a 24-hour period (941,200 acre-feet per year).

When the canal was constructed it was earthlined except for the last 38 miles, from near the North Shore to Lake Cahuilla, which were concrete-lined. This concrete-lined portion is 40 feet wide and 12 feet deep.

To save an estimated 132,000 acre-feet of water annually which had been lost through seepage, the first 48 miles of the Coachella Branch were replaced with a 48-mile long concrete-lined canal in 1980. This leaves 36 miles of unlined canal along the Salton Sea between Niland and North Shore. The District is seeking funding to complete the lining to save even more water.

The recent conservation project cost $45 million. Under the terms of a contract between the District and the United States, the cost of the project will be repaid over a 40-year period with the federal government making the annual payments until the District begins to benefit from the saved water.

Colorado River Water Distribution

Average annual flow	13 8 million ac-ft
Basin Divisions	
Upper basin states Wyoming, Utah, Colorado, New Mexico	7 5 million ac-ft
Lower basin states California, Nevada, Arizona	7 5 million ac-ft
Lower basin states (Additional water if available)	1 0 million ac-ft
Mexico	1 5 million ac-ft
Evaporation, etc.	1.0 million ac-ft
Total Basin Evaporation	18 5 million ac-ft
Lower Basin States Allotments	
California	4 4 million ac-ft
Arizona	2 8 million ac-ft
Nevada	300 000 ac-ft
Priorities Within California	
1 Water to irrigate 105,500 acres in Palo Verde Irrigation District. 2 Water to irrigate 25,000 acres (California Division). 3a Imperial Irrigation District and Coachella Valley Water District 3b Water to irrigate an additional 16,000 acres in Palo Verde	3 5 million acft
4 The Metropolitan Water District of Southern California	550,000 ac-ft
5a The Metropolitan Water District of Southern California	550,000 ac-ft
5b City and County of San Diego	112,000 ac-ft
6a Imperial Irrigation District and Coachella Valley Water District 6b Water to irrigate an additional 16,000 acres in Palo Verde Irrigation	300,000 ac-ft

Initially, saved water is being sent to Mexico to help meet treaty obligations between the two countries. According to the terms of the treaty, Mexico is entitled to 1 5 million acre-feet of Colorado River water annually.

Prior to reconstruction, IID maintained the Coachella Branch from the main All-American to near Niland. Some land within the IID south of Niland is irrigated from the canal. Now the entire Coachella Canal is under the jurisdiction of the District.

LAKE CAHUILLA

Lake Cahuilla, terminal reservoir on the Coachella Branch of the All-American Canal, was constructed in 1969 to serve as storage for a reserve supply of irrigation water.

Since it takes water three days to arrive in Coachella Valley after being ordered from Imperial Dam, the lake gives the district some latitude when weather conditions change unexpectedly.

Constructed at a cost of $1.56 million, exclusive of rights-of-way and land acquisitions, the lake was financed by a rehabilitation and betterment loan from the U.S. Bureau of Reclamation approved by voters in the Colorado River service area.

Improvement District 1 is the area that has been paying taxes that finance the Coachella Canal.

- 85 % of farms are using canal water.
- 15 % are using well water.
- 58,033 acres are being farmed.
  - 7,000 acres are being double cropped
  - 1,736 acres use sprinkling for germination then use drip or flood irrigation.
- 35,470 acres utilize flood irrigation.
- 27,827 acres or 48 % use drip irrigation.
- Grapes -- 13,788 acres
  - 5,411 acres in flood irrigation.
  - 8,377 acres in drip irrigation.
- Citrus -- 16,251 acres
  - 4,855 acres in flood irrigation.
  - 11,396 acres in drip irrigation.
- Dates -- 6,212 acres
  - 4,251 acres in flood control.
  - 1,961 acres in drip irrigation
- Row Crops -- 21,790 acres
  - 15,697 acres in flood irrigation
  - 6,093 acres in drip irrigation

SECTION 8
FEDERAL PARTNERSHIP AGREEMENT

An agreement to cut red tape and fast track projects through mutual cooperation and close communication became the first of its kind in the nation when the District and the federal Bureau of Reclamation approved its provisions (1995).

The "partnership agreement," pushed by former Commissioner of Reclamation Dan Beard, describes how the Bureau of Reclamation and the District will work together to "identify, address and solve joint problems (technical, legal, organizational, and administrative) and improve the management of water resources in Coachella Valley."

Working together, the partners intend to:

- Define "reasonable beneficial use" of irrigation water in Coachella Valley to help determine opportunities to optimize use of supplies. Unless water is put to "reasonable beneficial use" it is considered wasted under both state and federal law.
- Resolve land classification issues to clear up the legality of using reclamation project water to irrigate certain fields.
- Work toward removing farmland in the Coachella Valley from the water use restrictions of the Reclamation Reform Act to allow better management of both supplemental imported water and groundwater.
- Work toward a collaborative atmosphere that will allow all California Colorado River irrigation water users to determine distribution of the total supply allocated to them.
- Evaluate and, if appropriate, expedite transfer of title of the Coachella Canal to the District.
- Work with the Metropolitan Water District of Southern California and the Imperial Irrigation District to expedite the concrete lining of the main All-American Canal to prevent seepage water losses.
- Create a management plan for Coachella Valley that will meet water demands through a mix of surface and underground supplies.
- Pursue legislation, if necessary, to bring about agreed upon changes.
- Pursue creative approaches to utilize the Yuma desalinization plant. This plant, the world's largest when built, was constructed to desalt water from Arizona farm drains so it could be delivered to Mexico as part of that country's Colorado River share. Extremely expensive to operate, it was mothballed after a brief time in service.
- Develop programs to increase public awareness and feedback regarding water management activities.

In an effort to determine the "reasonable beneficial use" issue a few years ago, the Bureau of Reclamation, the District and the Imperial Irrigation District agreed to bring in an independent team of water use experts to study both valleys. When the experts attempted to determine on-farm use, Imperial Irrigation District pulled out, ending the study.

Under this partnership agreement, the District will review the leaching (flooding of fields to wash out salt build-up) and water use practices of 15 percent of the lands within its service area each year until all have been reviewed.

As part of the implementation of this study, the District has started requiring a water audit as a condition of any new irrigation water service.

Before canal water became available to Coachella Valley farmers, the Bureau of Reclamation classified lands based on irrigability. Class 6 soils were so sandy and porous that they were determined to be not irrigable.

Located mainly on the sunny slopes along the sides of the valley, these lands became home of some of the most productive grape vineyards upon invention and application of drip irrigation.

The District applied for reclassification of these lands several years ago and has authorized water use of some of the farms with the restriction that Class 6 land cannot be flood irrigated. Only the more water conserving drip or sprinkler systems can be used.

Reclassification of these lands to officially receive the Bureau of Reclamation's blessing for water use on them had been bogged down in red tape for several years. As a result of this partnership agreement, Bureau of Reclamation officials completed this land reclassification and are attempting to respond more quickly to any additional lands submitted for reclassification in the future.

The Federal Reclamation Reform Act restricts delivery through federal water projects to some types of land ownership and limits the amount of land that can be irrigated. In the Coachella Valley, this restriction had forced total reliance on well water on large areas of land which otherwise would have been able to irrigate with canal water. This forced use of groundwater was one of the contributors to the declining water table.

Once a local agency pays off its federal construction contract obligations, it no longer is subject to these restrictions. Full implementation of the District's water management plan required the ability to more effectively use both groundwater and surface water.

While the District had nearly completed repayment obligations for construction of both the canal and distribution system, a project to line 48 miles of the Coachella Canal to make water available to meet federal treaty obligations to Mexico by saving water lost through seepage had been accidentally listed as a reclamation project instead of the federal salinity control project that it was

This project, which is being paid for, so far, by the federal government because it benefits from the water, would not be paid off for another 25 years and was preventing the District from getting out from under the Reclamation Reform Act provisions

After years of effort, this was quickly accomplished after signing of the partnership agreement.

Through the accumulation of credits for project improvements applied toward debt, District farms were out from under reclamation law by June 1996.

SECTION 9
COACHELLA VALLEY WATER DISTRICT STATISTICS

DISTRICT SERVICE . . . . BY THE NUMBERS

GENERAL INFORMATION

Local government agency formed -- 1918, storm water unit, 1915.

Governing board -- 5 directors elected to 4 year terms.

Fields of service -- Importation and distribution of domestic water; wastewater collection, reclamation and redistribution; regional flood protection; importation and distribution of irrigation water; irrigation drainage collection; groundwater management; and water conservation

Service area -- 637,634 acres, 375,658 acres in storm water unit, lying mainly in Riverside County with territory in Imperial County and a small portion of San Diego County.

Property valuation -- Properties within the District have a total combined full value of $16,378,410,009 as fixed by Riverside and Imperial counties' assessor and state official in charge of utility properties

IRRIGATION WATER SERVICE

WATER USE IN ACRE-FEET

Fiscal Year 1995-96	
Total irrigable area (acres)	78,553
Active accounts	1,234
Total Sales	297,940
Average daily consumption	816
Maximum daily demand	1,414
Average use/crop-acre (multiple crops)	4.15

System	
Reservoirs	2
Storage capacity, acre-feet	1,301
Distribution system, miles	485
Pumping plants	20
Canal, miles	122

URBAN CONSERVATION

IN ACRE-FEET

Fiscal Year 1995-96	
Reclaimed from sewage	11,614
Imported supply since 1973	1,248,359

DOMESTIC WATER SERVICE

WATER USE IN GALLONS

Fiscal Year 1995-96

Population served	164,703
Active meter services	65,881
Average *home* use, per person/day	248
Summer per person/day	302
Sales, billion gallons	29
Sales, acre-feet	89,008

System

Active wells	85
Reservoirs	55
Storage, million gallons	86.6
Distribution lines, miles	1,523
Fire Hydrants	10,162
Wastewater reclamation plants	6
Daily capacity, million gallons	18.8
Collector system, miles	835
Active services	55,963
Average population served	139,908
Avenge daily flow million gal	13.4
Annual flow, billion gallons	4.82
Annual flow, acre-feet	14,802

Regional Stormwater Protection, Miles

Whitewater River Channel	24
Coachella Valley Channel	24.5
Eastside Dike	25.5
Detention Channel 1	3.25
Detention Channel 2	2.25
Detention Channel 3	1.75
Westside Dike	4.5
Ave. 64 Evacuation Channel	6.75
La Quinta Evacuation Channel	4.5
Bear Creek Channel	3.5
La Quinta Channel	1.75
Deep Canyon Facilities	5
Dead Indian Canyon Facilities	2.75
Palm Valley Channel	6
E. Magnesia Canyon Channel	1.75
W. Magnesia Canyon Channel	1.25
Thunderbird Channel	1
Villas Stormwater Channel	.75
Peterson Stormwater Channel	.5
Sky Mountain Channels	1.75
Rancho Mirage Drain System	3
Portola Avenue Drain System	5
North Portola Avenue Storm Drain	1.3

Agricultural Drainage

On-farm lines added, miles	2.24
Total on-farm drains, miles	2,291
District open drains, miles	21
District pipe drains, miles	166
Acreage with farm drains	37,545